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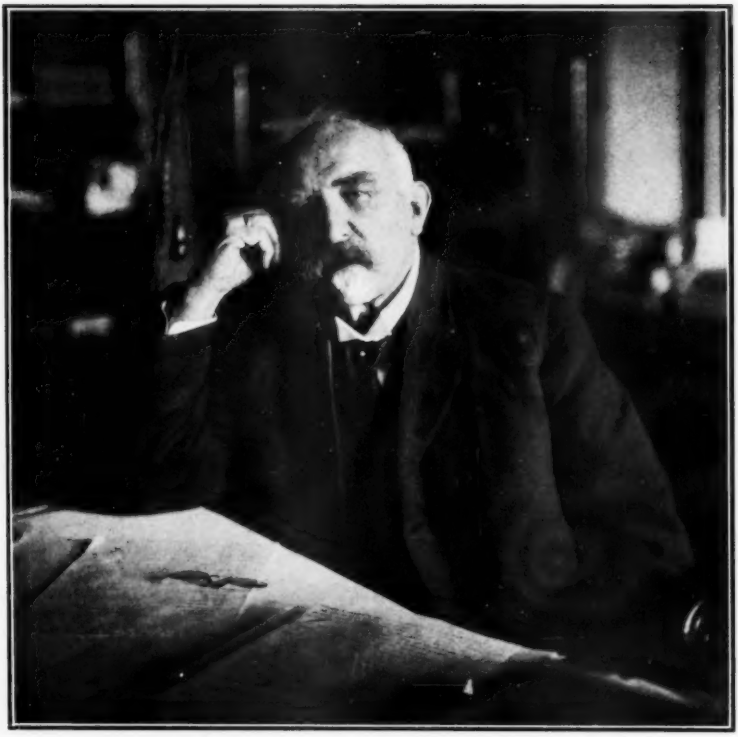

OTTO JULIUS KLOTZ, 1852-1923

(In the Office of the Director, Dominion Observatory, Ottawa)

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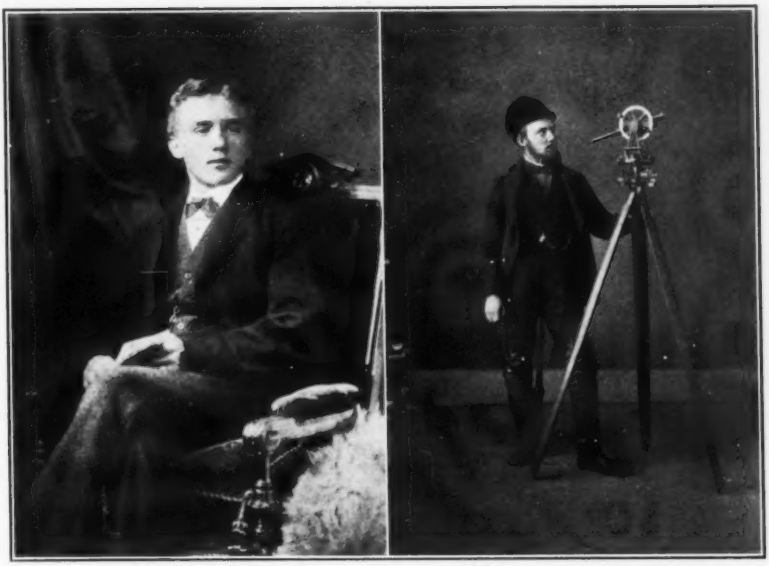

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OTTO JULIUS KLOTZ

THE JOURNAL
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VOL. XVIII JANUARY-FEBRUARY No. 1-2

DR. OTTO KLOTZ

Director of the Dominion Observatory, Ottawa

By R. MELDRUM STEWART

THE death of Dr. Klotz on December 28, 1923, was a great loss to Canadian science, to the Government service, and especially to the Dominion Observatory, with which he had been associated since its inception, and of which he was Director for the last six years. With him passes away the last of the earlier generation of Canadian astronomical workers, whose work, beginning in the eighties, was gradually developed and finally came to fruition in the founding of the Dominion Observatory.

Dr. Klotz had been in failing health for some time. For many years he had been troubled with a slight affection of the heart, which impaired his physical activities, though not his mental vigour and alertness. This was probably more or less aggravated by the somewhat strenuous experiences (for a man of his years) of his trip to Europe in the spring of 1922 as Canadian delegate to the Rome meeting of the International Astronomical Union. In September, a few months after his return, the onset of further complications necessitated the giving up of his hitherto regular

attendance at the office, though he still followed carefully and took the keenest interest in all developments of the work of the Observatory. There followed a long hard winter, which only his grim determination and buoyant hopefulness carried him through. With the advent of spring his health improved somewhat, and the earliest possible moment found him again at his desk for several hours each day. Failing strength, however, would not be denied, and in October he was again confined to the house, on this occasion for the last time. His attitude in these last months was an interesting study of indomitable purpose: day by day, to within a few weeks of the end, he looked forward to a speedy return to his duties—"to-morrow or next day"—a to-morrow which was never to come.

Born in the village of Preston, Ontario (at that time Upper Canada), on March 31, 1852, Otto Klotz received his early education in the public school of the village. His father was Otto Klotz, notary public and the author of a German grammar for use in public schools; there was no one a more ardent advocate for the introduction of free public schools in Canada than he, as shown by correspondence on the subject between him and Ryerson. As was more common in that day than this, the teacher, James Buchanan, himself a man of considerable educational attainments, was able and enthusiastic enough to organize a class of about a dozen boys and girls and put them through a fairly thorough course in Euclid and Natural Philosophy.

In 1865 the thirteen year old lad won a scholarship entitling him to free tuition in the Berlin High School, and the following year a similar scholarship for the Galt Grammar School; the latter he accepted, and on April 16, 1866, entered the then famous school of Dr. Tassie, well known throughout the Canadas as an educator and disciplinarian.

His methodical habit of mind early manifested itself by the beginning on August 16, 1866, of a diary in foolscap form in which he entered his daily doings. This diary was continued in its original form for over fifty-seven years, up to within a few days of his death. Entries were religiously made every day during all that period, and during his later years he took a pride in telling that the only day missing was May 20, 1903—lost in going around

the world. It was his habit from time to time to enter short essays on the events of the day and questions of public interest, including such incidents as visits to foreign observatories and other institutions, or meetings with distinguished men.

After remaining for three years in the Galt Grammar School he matriculated to the University of Toronto in both arts and medicine, winning a scholarship in the latter course. As it was impossible to carry on two courses he finally selected the arts course including mathematics, astronomy and science. In those days the teaching in the two latter subjects was sadly deficient in Toronto, and the youthful student was forced to turn his face to the United States, finally selecting the University of Michigan at Ann Arbor, which he entered as a sophomore in 1870, graduating with the class of 1872. Among his classmates possibly the most distinguished was R. S. Woodward, the well-known scientist, who completed his career by being the first President of the Carnegie Institution at Washington, an office which he held up to his retirement within the last few years. These years too were marked by the formation of an acquaintance with Marie Widenmann, daughter of the German Consul at Ann Arbor, an acquaintance which culminated in their marriage on December 4, 1873. Their golden wedding was celebrated quietly some three weeks before his death.

Shortly after graduation he was offered posts in the United States both with the Lake Survey and the Coast and Geodetic Survey, but preferred to return to his native land and take up work as a surveyor and engineer. For several years he followed the private practice of his profession, and in November, 1877, successfully tried the examination for D.T.S. (Dominion Topographical Surveyor), the highest surveying degree in Canada. Two years later he received an appointment as contract surveyor for the Canadian Government, and was shortly after advanced to base line work, the highest class of surveys in the Northwest. It may be remarked that he was the first one (in 1881) to make a return of the nature of the soil removed from the pits dug to designate township or section corners, a practice which was subsequently generally introduced and adopted by the Department. In 1885, when a local board of D.L.S. examiners for British Columbia was formed, he was one of the appointees, the other members

being E. Deville, Wm. Ogilvie and Thos. Drummond. Two years later, in June, 1887, on the resignation of Lindsay Russell, he was appointed by order-in-council to the regular board of examiners, a position which he occupied till his death.

As early as 1884 the question of the feasibility of the Hudson bay route to Europe had come up. In that year an expedition was fitted out on the steamer "Neptune", which deposited observers at various points along Hudson strait and in the bay to report on ice and weather conditions. At the same time Mr. Klotz was entrusted with an overland exploration survey, following the South Saskatchewan to its junction with the North Branch, thence to Cumberland House and through Cedar lake to lake Winnipeg, continuing down the Nelson to Hudson bay and York Factory; the return trip was by the canoe route of the Hudson's Bay Company up the Hayes river and through Oxford lake. The expedition comprised two Peterborough canoes and four men; it covered two thousand miles, involving eighty-seven portages. On account of the shallowness of the water about York Factory and Nelson he reported adversely to making either the terminus of any contemplated railway to Hudson bay; the commercial value of such a railway he also questioned in any event.

The entrance of British Columbia into Confederation introduced a new phase into the survey work of the Department of the Interior. It will be remembered that one of the conditions of Confederation was the granting by British Columbia to the Dominion of a strip of land twenty miles wide on each side of the Canadian Pacific railway and parallel thereto. It was manifestly impossible, on account of physical difficulties, to extend the existing system of surveys to and through the mountainous regions of British Columbia; the only alternative was a detailed azimuth survey tied in here and there to points whose latitude and longitude had been determined with precision by astronomical methods. This entailed astronomical observations, which were put under the charge of Mr. Klotz, and he was the first one to whom the title of Astronomer was officially given by the Department. Several stations were established in 1885, using Seattle as a preliminary base-point for the longitudes, as being the nearest station of which the longitude was even approximately known. Within the

next two years the chain of stations was extended eastward to Port Arthur, and later to eastern Canada. To cope with the ever increasing demand for astronomical positions, arising from the necessities of Dominion Lands surveys, the coördinating of these and other surveys for mapping purposes, and the delimitation of the international boundaries, the Astronomical Branch of the Department of the Interior was established, to develop later, in the course of events, into the Dominion Observatory.

In connection with the survey of the Railway Belt, Mr. Klotz was the first to determine accurately the heights of the mountains in the Rockies and Selkirks and the Gold Range, and he named a number of well-known peaks, such as Mounts Macdonald, Tupper, Mackenzie, Tilley, Begbie, Burgess, Dennis, Hector and others.

Later he spent some considerable time in Alaska in connection with preliminary reports on the afterwards famous boundary question. His report was in several respects unfavorable to the Canadian contention, foreshadowing with remarkable foresight some of the points in the actual award of 1903. Other counsels however prevailed, and his connection with the question terminated.

His first trip to Europe was in 1898, when he was sent by the Government on a confidential mission to London, Paris and St. Petersburg. The opportunity was embraced of visiting a number of observatories, for, though we had as yet no Canadian observatory, the vision had been formed and events were slowly shaping themselves in that direction. The connections then formed were kept up ever after, to the mutual benefit of himself and Canadian astronomical science.

In 1902, on the completion of the All Red Cable route by the filling in of the last link between Canada and Australia, he was entrusted with the oversight of a longitude campaign to connect these two countries and to thus complete the first longitude girdle of the earth. With him in this work was associated Mr. F. W. O. Werry, and the undertaking was carried to a successful conclusion by a campaign extending over parts of 1903 and 1904. When the resulting longitudes of points in Australia were compared with those deduced from preceding determinations of longitude arcs from Greenwich, proceeding towards the east, they were found to agree within a fifteenth of a second of time or one second of arc.

On his return from Australia in 1904 by way of Europe he was granted by the University of Toronto the honorary degree of LL.D. Later this was to be supplemented by the degree of D.Sc. from his alma mater, the University of Michigan, and by the further degree of LL.D. from the University of Pittsburg.

Meanwhile, largely through the efforts of Dr. King, the Chief Astronomer of the Department, and himself, both of whom had persistently advocated it for many years, the project of a fixed Canadian observatory was gradually taking shape. At the outset their ideas were very modest—too modest perhaps; they dared not hope for the possibility of anything beyond a small observatory and office building, to house a fixed transit instrument and the necessary small longitude staff, with perhaps a toy equatorial for exhibition purposes. As time passed, however, their thoughts and hopes grew bolder, until finally the man of the hour appeared in the person of the Honourable Clifford Sifton, who, as Minister of the Interior, granted them all, and more than all, that they asked, and the Dominion Observatory became an assured fact. The new building was completed and occupied in the spring of 1905, with Dr. King as Chief Astronomer and Director, and a short time later Dr. Klotz was given the title of Assistant Chief Astronomer.

From the outset he had charge of the division of geophysics, including seismology, terrestrial magnetism and gravity. The latter he had already been engaged in to some extent, having carried with him on his Australian longitude campaign a set of invariable half-seconds pendulums of the Mendenhall type, with which relative determinations of gravity were made at all the stations occupied. The infant science of seismology he took up with his accustomed vigor and gave it his undivided personal attention for the next twelve years. During that period he built up a seismological station of the first rank, with a reputation surpassed by few if any in the world, which remains one of the enduring monuments to his memory. He is perhaps most widely known by the Seismological Tables issued by him in 1916. His place among the seismologists of the world was recognized by the Government in sending him as delegate to the international seismological meeting at the Hague in 1907, to Zermatt in 1909, to

Manchester in 1911 and to St. Petersburg in 1914—the last visit being interrupted en route by the war.

A systematic magnetic survey of Canada—one of the most extensive ever carried on in any part of the world—was inaugurated under his direction in 1907; this has been systematically carried on and extended to the present day, the field of operations having been carried to the Arctic circle and beyond during the summer of 1923. In the actual field observations, however, he took no personal part.

The field of gravity was less systematically pursued owing to the lack of observers to whom to entrust the field observations. Some fifty stations, however, were occupied in various parts of Canada up to the time of his death.

With the death of Dr. King, early in 1916, the natural sequence would have been the appointment of Dr. Klotz to the vacant Directorship. Coming as it did, however, in the midst of the world war, with national prejudices and hatred of all things German at fever heat, his German name told heavily against him. This fact, aggravated, as appeared later, by malicious rumors actively spread by a few former friends, created a storm of popular prejudice to which the Government thought it better in those strenuous days for the time being to bow; when, in the autumn of 1917, the appointment was finally made, there was heartfelt rejoicing among the staff, who had been for eighteen months without a head, and with whom Dr. Klotz was deservedly popular. It is hard to realize what must have been his feelings during those long months of unjust suspicion and isolation; as a matter of fact no sturdier Canadian existed anywhere, as evidenced by his whole life history—exemplified by the fact that the only one of the family of military age (a nephew) was killed in action at the front.

On his appointment as Director he gave up in large measure his personal work in seismology and devoted himself to the oversight of the wider problems of observatory work as a whole. When in 1920 Canada gave her adherence to the International Astronomical Union organized at Brussels the previous year, he was elected Chairman of the National Committee of Canada; he was also a member of three of the international committees of the Union, as well as of the Canadian National Committee for the

International Geodetic and Geophysical Union. In 1922 he was appointed Canadian delegate to the Rome meeting of the International Astronomical Union in May of that year, and also represented Canada at the seven hundredth anniversary of the founding of the University of Padua in the same month.

He was a member of many learned societies, among which may be mentioned the Royal Astronomical Society of England; the Royal Society of Canada, being president of Section III in 1922; the Royal Astronomical Society of Canada, of which he was for some years honorary president; the American Association for the Advancement of Science; the New Zealand Institute, of which he was the only member in Canada; overseas member of the Norman Lockyer Observatory Corporation; ex-president of the Seismological Society of America; vice-president for three years of the American Astronomical Society; honorary president of the Dominion Land Surveyors' Association; and many others.

Between 1882 and 1922 he published ninety-nine papers besides his many official reports. His writings cover astronomy, seismology, terrestrial magnetism, gravity and the wider fields of general geophysics. He had a gift of popular exposition all too rarely found in the scientist, and his public lectures had a breeziness and charm that put him in instant touch with his audience. He filled a worthy place in the early development of astronomical science in Canada, and his loss will be felt keenly by his fellow-scientists in many varied lines of work in this and other countries, as well as by a host of warm personal friends and admirers.

THE ABSOLUTE MAGNITUDES AND PARALLAXES OF 1080 STARS

By R. K. Young and W. E. Harper

I. Introduction

THE parallaxes of approximately eleven hundred stars have recently been completed by the spectroscopic method and the manuscript is in course of preparation for the printer. A very brief abstract of the scope of this work was published in the report of the meeting of the American Astronomical Society at Pasadena.[1] We consider it important to make available to astronomers not only the mean results but also the values of the absolute magnitudes for each observer from the several spectral lines. A publication of this extensive material will necessarily take several months in going through the press and we propose in this place to present some of the main conclusions and in particular to present the results for the later K-type and the M-type stars. The results for the K-type giants are quite contradictory to the Mount Wilson values.

On the completion of the observatory in 1918, the first extended programme of observation undertaken was the determination of the radial velocities[2] of several hundred stars from Boss' General Catalogue. It was intended to use the plates taken for radial velocity determinations to obtain the parallaxes by the spectroscopic method then just recently developed by Adams and Kohlschütter.[3] These observers discovered that certain lines in the spectra of the stars showed a marked variation in their intensities between stars of high and low luminosity. Among other lines, they mention λλ4077, 4215, 4290, 4455, 4462, 4494. Before this method could be applied to our spectra, however, it was necessary to obtain empirical curves relating the line intensity in the spectra

[1]Popular Astronomy, Nov. 1923.
[2]Pub. Dom. A'p'l Obs'y, Vol. II, No. 1.
[3]Contrib. Mt. Wilson Obs'y, Vol. 5, p. 67.

obtained at this observatory with the absolute magnitudes and this involved the photographing of spectra of stars with known parallax. This work was commenced in 1918.

The general method was planned along the lines discovered by the Mount Wilson observers but several factors seemed worthy of investigation. A search was to be made for new lines which would show a change in intensity with luminosity. It is obvious that the more lines that can be used, at least up to a fairly large limit, the smaller will be the accidental error of measurement for the mean. A casual inspection of the spectra of some stars of known parallax is sufficient to satisfy oneself that fairly large accidental departures from normal for any one line do occur. Another point to be investigated was the method of measuring the intensities of the lines. The Mount Wilson observers had adopted the plan of measuring the *ratio* of the intensity in pairs of lines in terms of a unit called a *step*. In the publication of the parallaxes of 1646 stars[4] they recognize an intensity ratio as large as ten steps. Considerable work was done here in 1918 in making a standard scale so that the quantity which we called a step might remain constant and be fairly well defined. The construction of this standard and the method of using it will be described in a section by itself. A start was made also in obtaining spectra of stars with known parallax. It was soon discovered, however, that it would be necessary to obtain spectra of a great many stars because the correlation of line intensities to absolute magnitude is complicated also by variations with type. It is necessary to have a sufficient number of stars to determine the relations for all the types. Moreover, the reliability of the method among the giants seemed somewhat doubtful and as here especially large numbers of spectra are necessary the problem involved a great deal of observation. In the meantime the radial velocity programme was pressing and it seemed best to complete this part of the work first. The radial velocity programme was completed in 1921 and the absolute magnitude work resumed by the writers conjointly. Each observer has shared equally in the observational part of the programme and both have measured all the plates and derived independent reduction curves.

[4]Contrib. Mt. Wilson Obs'y, Vol. 9, p. 423.

II. Programme of Observation

The radial velocity programme undertaken in 1918 was compiled from Boss' Preliminary General Catalogue and included 720 stars between the fifth and eighth magnitudes. The basis of selection for these stars was position. We observed all the stars in the even minutes of right ascension north of the equator which had not been previously observed. The odd minutes of right ascension and all stars south of the equator were omitted as these were being observed at Mount Wilson. The basis of selection makes no assumption concerning the proper motions. Only a little over half the stars were of types later than F0 and so suited for obtaining absolute magnitudes. Moreover for very few of the stars had parallaxes been published and in order to obtain sufficient data we made out an additional programme of 500 stars whose parallaxes had been determined at one or more observatories, special attention being given to the modern parallaxes. This latter programme is undoubtedly biased in regard to large proper motions for the early parallax observers selected stars with large proper motions as ones likely to yield positive parallaxes. At the same time the great majority of the large proper motion stars have yielded fairly large parallaxes and as these have been used directly the remaining stars which had to be treated by proper motion methods are freer from this objection than they might otherwise be. Moreover, practically all the bright stars of the northern skies are included so that the basis of selection is nearly one of apparent magnitude. In addition to these two programmes stars have been observed from time to time from the Harvard Revised Photometry and those of type later than A5 when suitable have also been used.

All the plates have been obtained with the one-prism spectrograph and medium length focus camera attached to the 72-inch telescope. This instrument has been described in Volume I, Number 1 and in Volume II, Number 1 of the Publications of the Dominion Astrophysical Observatory so that it is necessary only to give relevant details. The aperture of the collimator objective is 2.5 inches and its focal length 45 inches. The camera lens used has an aperture of 3 inches and a focal length of 28 inches. From

May 7, 1918, to August 12, 1919, we used a sixty degree prism made by Hilger and loaned by Professor Chant of the University of Toronto. Since August 12, 1919, we have used a slightly denser prism of sixty-two degrees angle also made by Hilger. Both these prisms give excellent definition. The latter gives a dispersion at Hγ of about 29A per millimeter while the first prism gave a dispersion of 34.8A. On spectra taken with either of these prisms, the iron arc doublets at λ4187 and λ4200 each of which are separated by about three-fourths angstrom are clearly resolved with a slit width .0015 inch while the limit of resolution is about one-half angstrom.

Variations in the dispersion and purity of the spectra must undoubtedly have a large effect upon the estimates of line intensity but for our results we may say that the plates have practically all been obtained with the same dispersion. Fully 95 per cent. of the parallax stars have been observed with the higher dispersion. For these stars two good spectra were obtained. For the Boss stars six plates were obtained as a rule and while some of these plates were obtained with the slightly smaller dispersion in almost every case two or three spectra were obtained with the larger angle prism. Stars taken from the Harvard Revised Photometry which have been observed subsequent to the completion of the radial velocity programme likewise have been observed with this instrument so that the observational material is fairly homogeneous.

III. Lines Used for Absolute Magnitude

The following table contains a list of lines we have used for the determination of absolute magnitude. They include those discovered at the Mount Wilson Observatory and several others.

Our results indicate that both lines forming the ratios which we have measured show variations with absolute magnitude. We illustrate in Fig. 1, curves 1, 2, 3, 4, what seems to us would be the result if we could measure the intensity of each line separately. In these curves the ordinates are intensities and the abscissae are absolute magnitudes, the dwarfs being to the right. Curve 1 illustrates a line which shows a rapid change in intensity in the giant stars but which shows less or no variation in the dwarf stars, that is, the curve becomes asymptotic to some horizontal

TABLE 1

Ratio λ : λ	Used in Spectral Types	
	Young	Harper
4071.9 : 4077.9	A5.....M6	A5.....M6
4161.6 : 4167.6	A5.....K2	A5.....K9
4202.2 : 4207.0	G5.....M6	G4.....M6
4215.7 : 4250.6	A5.....K2	A5.....K2
4247.2 : 4250.6	A5.....K2	A5.....K9
4258.5 : 4260.6	F2.....M6	A5.....M6
4271.7 : 4290.1	A5.....G4	A5.....G4
4455.1 : 4462.0	F8.....K9	F8.....K9
4455.1 : 4494.7	G2.....K9	G0.....K8
4455.1 : 4482.4	G6.....M6	G6.....M6
4455.1 : 4489.4	G5.....M6	G6.....M6
4482.4 : 4494.7	M0.....M6	G8.....M6
4489.4 : 4494.7	G5.....M6	G8.....M6
4494.7 : 4496.5	G5.....M6	G8.....M6

line. Curve 2 illustrates on the other hand, a line which is of little or no use to distinguish between various grades of giants but which is a sensitive criterion for absolute magnitude in the dwarfs. Curves 3 and 4 are still other types of variation. When we measure the ratio of a pair of lines we may get any combination of these types of curves. If the two lines forming the ratio are of types 1 and 2, one of the resulting possible curves that we would obtain is shown in curve 5. Curve 6 illustrates what might be the result of measuring the ratio of a pair of lines which behave like curves 1 and 4. Depending on the spectral class where the lines begin to show and the extent of their variations, we may get a great diversity of resultant curves connecting the step values for a pair of lines and the absolute magnitudes.

We append a description of the behaviour and character of each of the lines used.

4071 : 77. In the earlier types A5—these two lines are free from blends. There is a component to the red side of 4077 but as a rule it is well enough resolved not to interfere with the measures. Both lines become more involved with other lines in the later types and unless the plates are well exposed the estimation of the

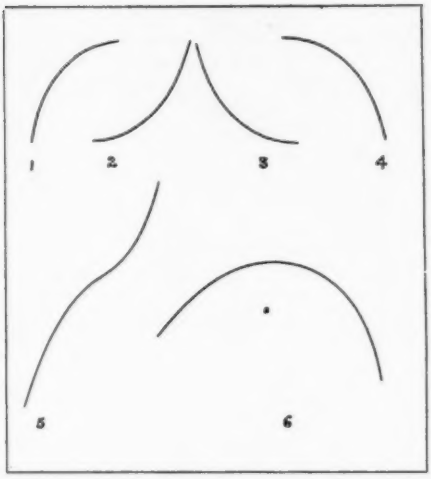


FIG. 1

relative intensity of the lines is subject to a large accidental error. On well exposed plates, however, the variation with absolute magnitude is pronounced over the complete range of spectral types examined. The variation seems to be almost linear. In types earlier than FO the curves are not well established either for this or the other lines but so far as can be judged from the limited number of A stars which we have studied, this line may be used as a criterion for absolute magnitude in types as early as A2, provided there are numerous metallic lines present in the spectrum.

4162 : 68. Like the preceding ratio, the lines in this pair are free from blends in the early type stars but become more involved in the later types. The line 4162 which is due to Strontium. seems to be responsible for the great variation of the ratio in the giants. The ratio is quite reliable in the F- and early G-type stars but is not so good later as some of the stars show rather large residuals and the curve in the extreme dwarfs reverses.

4202 : 07. The line 4207 was mentioned by Adams as of possible value as a criterion for absolute magnitude. It does not show very well until the star has reached type G. Both it and 4202,

with which it has been compared, are situated close to other spectral lines and unless the spectrum is fairly strong in that region the measures are unreliable. In the very giant stars the line λ4207 is considerably stronger than the line λ4202 and there is a rapid change in the relative intensity as the absolute magnitude becomes more dwarfish. In the extreme dwarfs, however, the line λ4202 seems to diminish more rapidly than λ4207 and the ratio is not so much positive there as in stars a little more luminous.

λλ4215 : 50. This pair of lines has been the subject of very careful investigation because it is one of the principal pairs upon which the absolute magnitudes of the giants, as determined by the Mount Wilson observers, rest. The nature of our results for this line can be best studied from our tables published in Section VI but we will describe what we consider the behaviour of this ratio. In types as early as F8 it consists of a curve similar in shape to curve 6, Fig. 1, though extending possibly less on the descending giant branch. In the dwarf stars λ4215 and λ4250 are almost equal or λ4250 may be even the stronger. As we proceed toward the giants the line λ4215 gains greatly in strength and reaches a maximum somewhere near the absolute magnitude minus one. For the most luminous stars the line loses a little in strength. These characteristics continue in the G-type stars even up to G8 and later but as we come to type K the amount of the turning back is less pronounced so that by the time type K2 is reached the curve in the giants is almost asymptotic to a horizontal line. For this reason we think that in the giant stars of types K3 and later the ratio λλ4215 : 50 is of very little use as a criterion of absolute magnitude. It serves to distinguish a giant from a dwarf but it does not grade the giants properly.

λλ4247 : 50. This is a good ratio in the early type stars, especially in the giants, where λ4247 becomes equal to or stronger than λ4250. In the late types it is very much involved in other faint lines which make the estimation of its intensity uncertain. The measures of the two observers sometimes refer to different quantities, one taking one component only and the other estimating the blend effect. In spite of this handicap the line is of considerable value. In the late types λ4247 is so weak that the ratio is always negative and for types beyond K2 the step value is so large that

it is difficult to estimate. For this reason one of us has dropped this line in the late K's. The variation with absolute magnitude seems to be almost linear in the giants but in the later type dwarfs seems to reverse.

λλ4258 : 60. These two lines which are separated by two angstrom units, form a very nice pair for measurement. The ratio seems to vary continuously over a wide range of spectral types. The amount of this variation per absolute magnitude is not quite as great as for some other lines but the accuracy of measurement of lines close together makes up to a large extent for the smaller range shown. This remark applies to the ratio principally in the earlier types. In the later types it shows as large a variation as the other lines used. In the M-types the pair of lines are very clear and sharp and consequently easy to measure.

λλ4271 : 90. As in the case of λλ4215 : 50, we have devoted considerable time to this particular ratio. We find, in agreement with the Mount Wilson observers, that it is of use in the early types of all absolute magnitudes but only in the giants of later types. Beyond G4 the variation with absolute magnitude even in the giants seems to be small and as we have several other ratios here which show a large variation we have dropped this pair of lines. Our measures in the M-type giants show that it is of some value but not so good as the other lines we use.

λλ4455 : 62 *et seq.* The four ratios involving the combination of λ4455 and another line are excellent examples of the combined effect of two lines each of which varies. The line λ4455 is strong in the dwarf stars and, for stars of absolute magnitude three and fainter, grows in intensity rapidly. In the neighbourhood of absolute magnitude plus one or zero the line shows little diminution with increasing luminosity if it does not grow stronger. The line λ4462 seems to stay fairly constant in the dwarfs and the smaller giants but it grows weaker in the very luminous giants so that the ratio λλ4455 : 62 is more positive than it is in the less luminous stars. The ratio λλ4455 : 94 behaves in the same way and to a more marked degree. Both these ratios show curves similar to curve 6 in Fig. 1 but turned upside down. In contradistinction to the lines λ4462 and λ4494 both of which are weakened in the very greatest giants, the lines λ4482 and λ4489 are strong. Their great

increase in strength quite overbalances the small change in λ4455 in these stars so that the ratios λλ4455 : 82 and λλ4455 : 89, both of which are very positive in the dwarfs, decrease steadily as we pass to more and more luminous stars.

λλ4482 : 94. From what has been said of these two lines in the preceding paragraph it follows of course that this pair must show a small variation, which they do. In the giant stars of class K2 to M6 both the lines are clear and easy to measure which compensates partially for the smaller range shown.

λλ4489 : 94. It was mentioned in the discussion of the ratios beginning with λ4455 that the line λ4489 was very strong in the giants and that the line λ4494 became weak. This pair, therefore, makes a fine ratio for the giants and supergiants. It becomes negative as we pass to the dwarfs and reaches a minimum somewhere between absolute magnitudes plus two and plus four. For the extreme dwarfs it is more positive again. Another logical pair to measure would be the ratio λλ4462 : 94 which must also show a good result in the supergiants. These various combinations are, however, not all independent.

λλ4494 : 96. The lines forming this pair behave much the same way as the preceding pair. They are very easy to measure in the late types and the accidental error of measurement must be small.

The question of weighting the results from the various lines has been the subject of considerable thought. Some of the factors which should enter into the weight are:

1. The number of plates on which a line was measured.
2. The number of times a line was measured.
3. The exposure and definition of the plate.
4. The slope of the reduction curve connecting line intensity with absolute magnitude for that line.
5. The reliability of the line as judged from the average residual left from many stars.

The system of weighting, if it were logical, would have to be very complex. We have no doubt that such a system could be worked out and would improve the mean but it seemed to us

hardly worth while and we have adopted the procedure of taking straight means. In a few cases if a line seemed to give very discordant results (or was uncertain) it has been omitted or given half weight.

IV. The Standard Scale

An artificial spectrum was made showing absorption lines graded in intensity by uniform steps, the weak lines at one end and the stronger lines at the other. The standard was made as follows. A piece of opal glass was illuminated by an electric light and masked so that when viewed from the side away from the light an opening about one centimetre by ten centimetres was visible. In front of this opening and running at right angles to its length were placed twenty small wires one-half millimetre in diameter and four centimetres long. A camera was used to photograph the illuminated opening being placed at a distance such that the length of the image of the illuminated opening was seven millimetres. The images of the wires which show as absorption lines were about .04 of a millimetre wide. This is about the width of a good spectrum line when photographed with a one-prism spectrograph giving a dispersion of 30A at Hγ. An exposure of sixty seconds was given and then the end wire was removed and the exposure resumed for six seconds when the second wire was removed. The following exposures, expressed in seconds, were made, one wire having been removed between each: 60, 6, 7, 7, 8, 9, 9, 11, 12, 13, 14, 15, 17, 19, 21, 23, 25, 27, 30, 33, 37.

The plate was developed and the lines showed a good gradation in intensity, the faintest being just visible and the strongest clear and sharp, a very good match for some of the best spectral lines. Several trials were made and two scales finally selected, one of which was used by Young and one by Harper. In each of these scales the line width is about the same but the latter's scale shows a greater change per step.

Considerable experimenting was done also in an attempt to obtain a standard which would measure both intensities and widths. It was found too difficult, however, to reproduce the characteristics of spectral lines and the method was finally abandoned for the simpler procedure.

It must be emphasized, that in using the standard scale we do not attempt to match a line of the scale with a line in the spectrum. The standard scale is placed over the plate to be measured so that the artificial lines are beside those to be measured in the stellar spectrum and the mental picture of the relative intensity of the two stellar lines is carried over and equated to an equal ratio in the standard. The problem is to find a pair of lines in the standard scale which give the same intensity ratio as the two lines in the spectrum. It is convenient and probably the best procedure to select lines in the standard of about the same absolute intensity as the spectral lines and this can usually be done. This procedure is very much simpler than to attempt to find a line which matches in every way any given spectral line. In this latter case, the character of the edges of the line and its width enter. In the adopted procedure the comparison is always made between lines of the same character.

The constancy of the standard and the reliability of the method of measurement have been checked from time to time by remeasuring a number of stars and comparing the results. It has been found that even after comparatively long intervals one returns to the same values. Further, both scales have been used for the same stars by the same observer and the measures agree very well when the proper conversion factor has been applied to change from one scale to the other. We think that any other observer could use the curves we have derived connecting line intensity and absolute magnitude by making a similar scale and measuring a comparatively small number of stars to find the step value of the scale. It would be essential, however, to use spectra taken with an instrument giving about the same dispersion and purity as the spectrograph attached to the 72-inch telescope.

Figure 2 gives a graphical comparison of the step values obtained by the two observers from the same stars each using his own standard scale. In this curve the ordinates are steps on the scale used by Harper and the abscissae are steps on the scale used by Young. This curve would enable either observer to use the empirical curves connecting absolute magnitude and line intensity constructed by the other. If for instance for a certain pair of lines in a star Harper obtains an intensity difference of

6 steps he might convert this into an absolute magnitude by using 6 steps on his own curves or 13.3 steps on Young's. Conversely, if Young obtained 15 steps for the same pair of lines he might convert this into an absolute magnitude by using 15 steps on his own curves or 6.8 on Harper's. The shape of the curve depends primarily on the character of the standard scales but to a small extent it depends on the observer. That this is true can be seen from a comparison of Figs. 2 and 3. Fig. 3 is a comparison of the two scales when used by the same observer for a number of lines.

There is very little difference in the curves of Figs. 2 and 3 for steps below eight on Young's scale but for larger steps the difference increases till it is quite marked. The fact that two observers may use the same scale somewhat differently does not vitiate what has just been said about the practicability of either observer being able to convert his measured values to fit the empirical curves of the other.

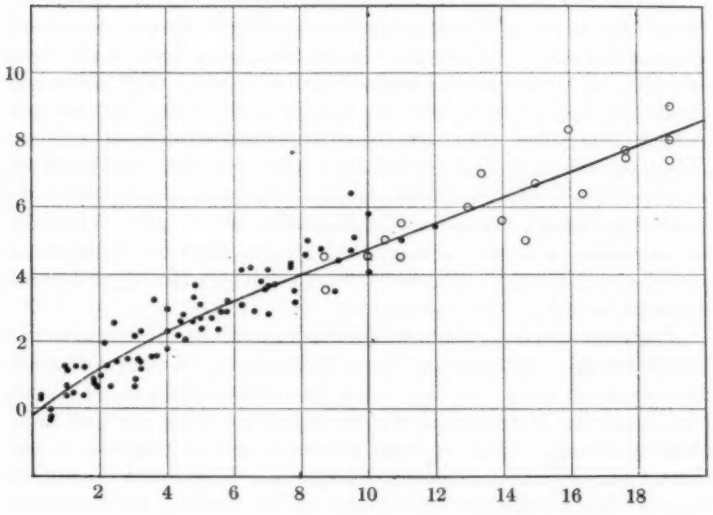


FIG. 2

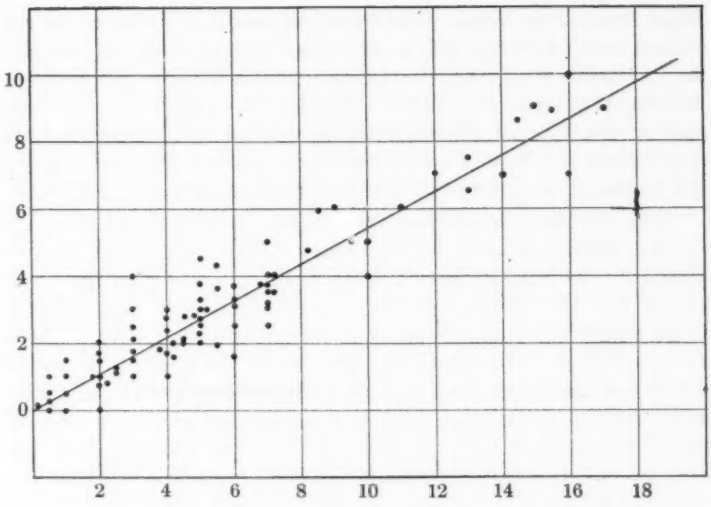


FIG. 3

V. THE DETERMINATION OF THE TYPES OF THE STARS

For most of the Boss stars and all the H.R. stars on our list no types were available save those given by the Harvard College Observatory. The experience of the Mount Wilson observers showed that the types as listed in the H.R. catalogue were subject to a fairly large accidental error and it seemed worth while to redetermine the types of the stars we were using. For some time we measured pairs of lines according to the method followed by the Mount Wilson observers but later discarded this method for the simpler procedure of eye estimates. The reasons for this were several. In the first place the measures of any pair of lines for type need a correction for absolute magnitude and the time spent in estimating several pairs of lines and reading values from curves was very much greater than direct eye estimates while the latter seemed sufficiently accurate. In the second place, the effect of any small error in the type did not seem to alter the absolute magnitude derived for the star because we use a rather

large number of lines. The usual tendency of an error in the estimation of the type was to make the agreement of the absolute magnitude derived from the various lines a little poorer without altering the mean very much. Besides, any small error in estimating the type of the stars by an eye estimate comes not so much from the lack of sensitiveness to spectral differences as to the indefinite nature of the Harvard definitions of spectral types.

The difficulty arises from the multiple nature of the Harvard criteria which are often contradictory. Thus we are told that in type A5 "the calcium line K is 0.9 times as intense as the compound line H and $H\epsilon$ and more intense than $H\delta$. Line λ4481.2 is no longer the most conspicuous among the solar lines." As a matter of fact if one takes the intensity of the calcium K line as a criterion one can find A5 stars showing scarcely any metallic lines whatever and on the other hand in many stars in which the calcium line K would place them in class A0 or A2, the metallic lines are very numerous and fairly strong. In the later types the Harvard criteria pay special attention to the hydrogen lines, the G band and the calcium line λ4227, all of which show variation with absolute magnitude. An inspection of the absolute magnitudes of the F-type stars shows that they are affected by this factor. Among the early F-types there are no stars as dwarfish as 5.0 or 6.0. The reason for this seems to be that in the very dwarf stars the hydrogen lines are weakened and the calcium line λ4227 is strengthened which favours the star being placed among the later types. The presence of small inconsistencies in the Harvard classification has been recognized for some time and the International Committee on Stellar Classification[5] remarks: "It is evidently ultimately desirable that each spectral class should be precisely defined, both by verbal description and by means of standard stars. The present moment, however, does not appear opportune for doing more in this way than has already been done at Harvard." It seems to the writers that if the system is to be definite the multiple nature of the criteria must be abandoned.

For our purpose all we wished was a system which would agree with the Harvard scale on the whole and which would enable us

[5]Trans. of the Inter. Astron. Union, Vol. 1, p. 95.

to place each star in a definite place in that scale. For types earlier than F we have used the ratio of the K line to Hδ or H+Hϵ as given by Harvard for the various divisions. If the star was definitely F0 or later, we shifted the attention to the ratio of the lines λ4227 and Hγ. These lines are about equal to each other in F8. For stars later than F8 we used the absolute strength of the line λ4227 up to and including K9 stars. The line λ4227 reaches its maximum strength about K9 or M0 and in the late M-types is much weaker. If our criteria showed the star as late as K5, we looked for the presence of the titanium oxide bands and when these were present the star was placed in class M. If the titanium oxide bands were not present the star was placed in the K-type, its exact place being fixed by the strength of the calcium line λ4227. We have chosen stars as typical of the various classes.

On one plate we have photographed, Vega A0, 101 Herculis A3, 15 Vulpeculae A5, ν Herculis F2, γ Serpentis F7. On another plate we have photographed ζ Herculis G1, β Boötis G5, α Boötis K0, π Herculis K3, γ Draconis K5, δ Ophiuchi K9 and α Herculis M6. In addition to these we have chosen the following stars as typical of the various subdivisions in the M-types for which we used as a criterion the strength of the titanium oxide bands, β Andromedae M0, α Orionis M1, η Geminorum M2, β Pegasi M3, α Herculis M6, R Lyrae M7, and 45 Arietis M8. Figures 4 and 5 show a graphical comparison of our types with those determined at Harvard and Mount Wilson. The ordinates are the Harvard magnitudes in Fig. 4 and the Mount Wilson magnitudes in Fig. 5, while in both the abscissae represent our own types.

The agreement of the Mount Wilson and the Victoria types is very good. In the early F-types we estimate one or two-tenths later and in the very late K-types we have several stars which we call K7 to K9, whereas very few stars in the Mount Wilson types are later than K5. Otherwise the agreement is almost perfect and the accidental error of both systems is satisfactorily small. As was pointed out before, we have made our criteria for type as simple as possible and we think that the small probable error which the types show, together with the fact that the division into types is perfectly definite, should go a long way toward establishing the simple criterion as a basis for selection of type.

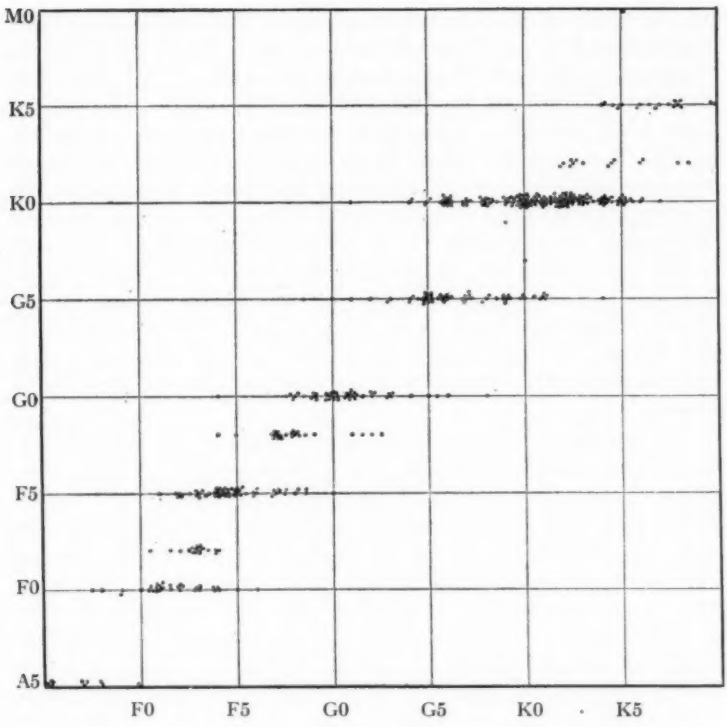


FIG. 4

The curve showing the relation of our types with the Harvard is not satisfactory. There is too much dispersion among the types determined at Harvard and inasmuch as our values are almost always in exact agreement with the Mount Wilson values and have been arrived at by independent methods we think there can be no doubt that the poor agreement with the Harvard types is due to the latter being subject to a large accidental error.

Before leaving the discussion of the types of the stars we refer to the class of stars with the c-characteristic. In the original classification of these stars by Miss Maury they were associated

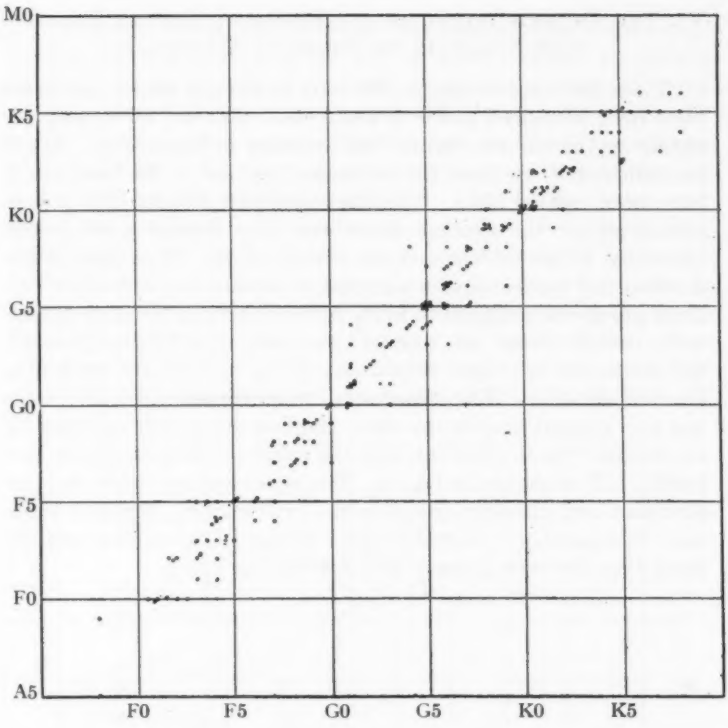


FIG. 5

with sharp lines. In spectra taken with low dispersion or with objective prism plates the lines may appear more sharp than those in other stars but they are not really so. In the c-stars many of the lines are very intense and fairly wide and so are not smeared over in instruments giving a low degree of purity. In our spectra many of the very finest line spectra are dwarfs. The fact that the c-stars have always been associated with sharp and narrow lines is particularly misleading at the present time when the density in the c-stars is known to be very low and one is inclined to ascribe the narrow character of the lines to the low density.

VI. The Determination of the Empirical Curves Relating Line Intensity to Absolute Magnitude

There are approximately 500 stars in our list whose parallaxes have been measured and it is these stars that we have used for obtaining the curves relating line intensity to luminosity. It will be sufficient if we show the procedure for one of the lines as all have been treated alike. The stars were first divided into groups containing on the average about ten stars though some groups contained as few as four and one contained 33. The basis of the division and the reasons for adopting it are outlined in Section VII. Each group was confined to fairly narrow limits in absolute magnitude, usually about one, and as there were only 49 groups in all, the dispersion in types within any group was about one-half a spectral division. The mean step value for the various groups was first plotted against the mean absolute magnitude as found by the Mount Wilson observers and the result of this plot for the line λλ4071 : 77 is shown in Fig. 6. The ordinates are steps and the abscissae are absolute magnitudes. Each circle represents the mean of a number of stars forming a group. This number and the mean type for each group is indicated in the figure.

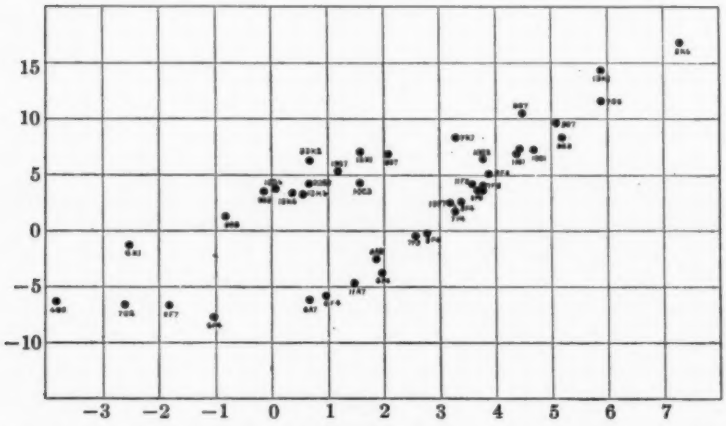


Fig. 6. Preliminary Relation of Line Intensity to Absolute Magnitude 4071:77

The graph enabled us to obtain a preliminary idea of the variation of the line with type as well as with absolute magnitude but because each group contained a fairly wide range in types the variation with this factor is not well shown. To obtain the variation with type more definitely we redivided the groups making the limits for the types in each group narrow and including wider limits in the absolute magnitudes. The limits chosen were about two-tenths of a Harvard spectral division and two absolute magnitudes. By means of the curves just drawn, the mean step value for each of these new groups could be reduced to what it would have been had the mean absolute magnitude for the group been the nearest integer. In this way we obtained the curves shown in Fig. 7 giving more clearly for each absolute magnitude the change in line intensity with type for the pair of lines λλ4071 : 77.

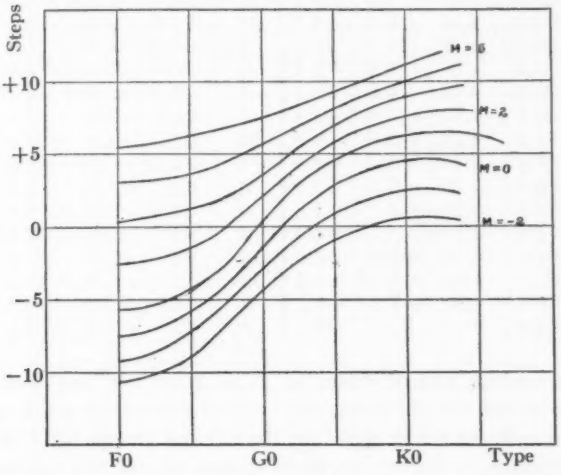


FIG. 7. Relation between Type and Line Intensity 4071:77

For each of the forty-nine groups of stars we next computed a new absolute magnitude as outlined in Section VII and co-related these with the mean step values for each line and each group. Columns one to four of Table 2 give the results of this computa-

tion for the line λλ4071 : 77. Column one gives the numbers of stars in the group and column two gives the mean type as determined here. Column three gives the mean absolute magnitude which we assigned to the group, while the fourth column gives the mean step value of the ratio λλ4071 : 77 for the various groups.

TABLE 2

No. of Stars	Mean Type	Victoria M	Mean Step	Reduced to F8	No. of Stars	Mean Type	Victoria M	Mean Step	Reduced to F8
7	G1.9	5.80	+ 8.4	+7.0	5	F4.0	2.60	− 6.0	− 4.3
7	G7.4	5.46	+10.5	+7.2	9	G6.0	−0.90	+ 1.2	− 5.1
10	G2.8	2.97	+ 4.3	+1.1	6	A7	+0.60	− 6.1	?
7	G8.0	6.23	+11.6	+8.1	11	A7	+2.01	− 4.6	?
10	G6.1	1.38	+ 3.8	−3.0	8	A8	+2.69	− 3.8	?
10	G2.0	3.85	+ 6.9	+4.9	8	F4.0	+2.36	− 3.8	− 1.9
10	G1.2	4.77	+ 7.2	+6.1	7	F3.0	+2.90	− 0.4	+ 1.3
7	G7.1	3.32	+ 6.9	+1.7	10	F4.0	+2.58	− 0.3	+ 1.4
9	G6.9	5.09	+ 9.6	+6.5	4	G0.5	−2.46	− 6.3	− 8.6
19	G7.0	1.09	+ 5.4	−2.1	8	F7.5	−2.95	− 6.6	− 6.1
11	G0.9	4.43	+ 6.9	+5.7	7	G2.0	−2.99	− 6.6	−10.0
7	F4.7	4.63	+ 3.6	+4.6	6	F4.0	−0.70	− 7.7	− 4.5
8	F4.2	4.18	+ 2.6	+3.8	22	G7.0	+0.10	+ 4.2	− 2.8
7	F7.3	3.75	+ 3.6	+4.0	6	K0.5	−4.14	− 1.2	?
10	F6.8	3.33	+ 2.5	+3.1	6	K0.5	+3.79	+ 8.2	?
6	F4.3	3.23	+ 1.7	+2.8	9	K1.0	+2.04	+ 7.0	?
10	F7.6	3.90	+ 4.2	+4.4	3	K6.0	+7.40	+16.8	?
7	F8.4	5.17	+ 7.3	+7.2	16	K4	−1.08	+ 3.4	?
9	F7.7	4.81	+ 5.1	+5.2	12	K1	+5.98	+14.4	?
11	F7.6	4.34	+ 4.1	+4.2	8	K6.5	+0.60	+ 3.3	?
8	G3.0	−0.46	+ 3.5	−1.2	3	K2	+0.50	+ 6.2	?

The various groups shown in Table 2 are not very well suited as they stand for obtaining the desired curves for each spectral type because the mean types for the various groups are fractional. The preliminary curves we have drawn giving the approximate variation of line intensity with type enable us to reduce the step values found for the various groups to what they would have been for closely neighbouring types. Column 5 in Table 2 shows the reduction of many of the groups to the type F8. The values in this column are plotted in Fig. 8. The open circles represent groups of stars that had to be carried forward or backward a con-

siderable number of type divisions and should, therefore, be given less weight than the filled circles which represent groups of stars comparatively near F8. The curves relating line intensity to type did not seem to us to be sufficiently trustworthy to justify us in carrying the A-type groups as far forward as F8 or the K-types backward. A curve drawn through the points in Fig. 8 represents a preliminary curve for type F8 showing the variation of the line λλ4071 : 77 with absolute magnitude. This curve is now based almost wholly on our own absolute magnitudes as opposed to the first curves drawn which rested on the Mount Wilson absolute magnitudes. Curves were drawn for each four-tenths of a main spectral division from F0 to K6. We had to employ a certain amount of smoothing out process in order that the curves would show a continuous variation from type to type which we assumed they should do.

Absolute magnitudes were computed for all the stars with the aid of the preliminary reduction tables and the mean for the groups taken. If this was not in agreement with the absolute

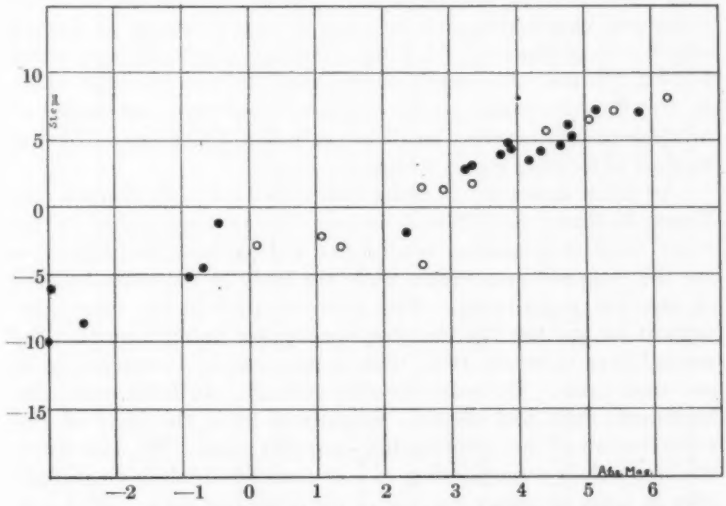


FIG. 8. Preliminary Curve showing Relation of Line Intensity to Absolute Magnitude for pair 4071:77, Type F8.

magnitude for the group which we had derived either from trigonometric parallaxes or proper motion data we assumed that our curves led to systematic errors and we corrected each of our absolute magnitudes by this amount. We considered that we would arrive in this way at a set of absolute magnitudes which would be systematically the same as our original material and which would have a much lower accidental error than affected the original parallaxes because our values were based on a considerable number of lines. This would be especially true in the small parallaxes. In the parallaxes as large as one-tenth of a second or a little less, if they had been observed several times, we still considered the trigonometric parallaxes superior.

We were now in possession of a preliminary absolute magnitude for each of our standard stars whose accidental error we believed was fairly small. The great advantage in having individual absolute magnitudes was, that the groups could be dispensed with and each type of star treated separately. We plotted the individual measures of line intensity and these new absolute magnitudes for each tenth of a spectral type. In order to increase the data the types were overlapped, that is to say, for the F1 curve we plotted all the stars of types F0, F1, F2; for the stars of type F2 we plotted F1, F2, F3, etc. The result of this work did not as a rule result in very drastic changes to the original curves but it did enable us in some cases to correct small errors which had crept in by the method of forming group means.

An abbreviated set of reduction tables for both Harper and Young is shown in Tables 3 and 4. In our unpublished tables every tenth of a spectral subdivision is listed and the arguments are the type and step values while the body of the table consists of absolute magnitudes. This latter method is the most convenient for use but has the disadvantage for publication that for several lines there are two absolute magnitudes corresponding to one step value. To overcome this difficulty we have made the arguments type and absolute magnitude while the body of the table consists of the corresponding step differences. We have listed the step values corresponding to every second absolute magnitude only in order to reduce the size of the published table. With few exceptions the tables might be expanded again. Any student who

desires to study further the accidental and systematic errors which affect our results will be in a position, with the help of these tables and the absolute magnitudes which will be published for each line, to reproduce our measured step differences for any star.

The preceding discussion relates to stars of type earlier than K6. In the later K- and M-types the difficulties are more numerous because in the first place we have practically no reliable parallaxes and secondly for about half our stars no spectroscopic parallaxes. This latter, however, did not so much matter as our experience in the late K-type stars led us to believe that the absolute magnitudes published by Mount Wilson for types later than K2 were rather unreliable. In any case we desired to have our results as independent as possible. The distinctions between dwarf and giant M stars did not concern us particularly because these are very apparent and only a few dwarf M stars were on our list. We desired reliable criteria for grading the giant M stars.

TABLE 3

F0

M	4071 / 77	4215 / 50	4271 / 90	4247 / 50	4258 / 60	4162 / 68
7.0	.....	−1.0	.....	.....	−6.4	.....
5.0	+2.7	+0.1	+1.8	.....	−5.1	−4.8
3.0	−0.7	+1.4	−0.7	−2.4	−3.9	−2.0
1.0	−3.2	+2.8	−2.8	+1.5	−1.8	+0.4
−1.0	−5.1	+4.5	−4.6	.....	−0.2	.....

F5

M	4071 / 77	4215 / 50	4271 / 90	4247 / 50	4258 / 60	4162 / 68
7.0	+5.6	−1.1	+5.1	.....	−6.4	.....
5.0	+2.7	+0.2	+2.7	−3.4	−4.8	−4.4
3.0	−0.2	+1.5	0.0	−1.8	−3.4	−1.4
1.0	−2.5	+3.1	−1.5	−0.6	−2.1	+0.2
−1.0	−4.3	+3.7	−4.5	+0.8	−0.9	+2.1
−3.0	−5.9	+2.7	.....	+2.4	+0.4	+4.4

G0

M	4071 / 77	4215 / 50	4271 / 90	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68
7.0	+6.8	−1.6	.....	+2.1	+4.6	−5.2	−6.4	.....
5.0	+3.2	+0.1	+3.5	+0.8	+3 1	−4.5	−5.0	−3.6
3.0	+1.4	+1.7	+2.3	−0.4	+1.8	−2.6	−3.7	−2.6
1.0	−0.4	+3.5	+0.9	−1.6	+0.7	−1.5	−2.6	−1.3
−1.0	−2.2	.....	−0.8	−1.6	+1.1	−0.5	−1.5	+0.2
−3.0	−4.2	+3.9	−3.0	−0.2	+2.4	+0.5	−0.5	+2.2

G5

M	4071 / 77	4215 / 50	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07
7.0	+7.6	−2.2	+2.3	+5.6	.....	−6.2	.....	+1.8
5.0	+4.0	0.0	+0.7	+3.5	−5.1	−5.1	.....	+3.5
3.0	+2.7	+2.0	−0.7	+1.9	−3.4	−4.0	−3.9 :	.....
1.0	+1.4	+4.2	−2.0	+0.8	−2.1	−3.0	−3.1	+3.5
−1.0	+0.1	.....	.....	+1.1	−0.7	−1.9	−1.7	+2.1
−3.0	−2.5	+4.8	−1.4	.....	+0.5	−0.7	+0.4	+1.1

K0

M	4071 / 77	4215 / 50	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4482 / 94	4489 / 94	4494 / 96
8.0	+8.0	−3.2	+4.2	+6.4	−8.4	−6.8	.....	.....	.....	+5.8	.....	.....	.....
6.0	+6.0	−1.3	+1.4	+3.8	−6.6	−5.6	−4.9	+4.0	+3.5	+4.2	+0.9	−1.3	+2.2
4.0	+4.4	+0.8	−0.4	+2.0	−5.3	−4.6	−5.4	+6.0	+2.1	+2.7	.....	.....	+2.7
2.0	+3.0	+3.3	−1.8	+0.8	−4.2	−3.6	−4.0	+4.0	+1.2	+1.4	−2.2	−1.8	+1.8
0.0	+1.7	.....	−3.2	.....	−3.1	−2.6	−2.7	+2.4	+0.5	+0.4	−1.1	−0.7	+1.0
−2.0	+0.4	+3.5	−3.7	+1.0	−2.0	−1.5	−1.4	+0.8	−0.3	−0.7	0.0	+0.5	+0.1
−4.0	−1.3	+2.4	−2.5	+2.4	−0.6	−0.2	+0.2	−0.8	−0.9	+1.8	+1.1	+1.7	−0.7

K5

M	4071 77	4215 50	4455 64	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4482 94	4489 94	4494 96
8.0	+7.5	−1.7	+4.6	+6.2	−7.2	−8.4	−1.2	+1.7	+4.4	+6.2	+2.3	+0.1	−0.4
6.0	+6.0	−0.7	+1.2	+3.8	.....	−7.4	−4.4	+4.5	+2.8	+4.5	0.0	−2.0	+2.4
4.0	+4.8	+0.4	−1.2	+1.9	.....	−6.4	.....	+5.9	+1.8	+2.9	.....	.....	+3.0
2.0	+3.4	+1.5	−3.1	+0.6	−7.7	−5.3	−4.0	+4.0	+1.0	+2.2	−1.5	−1.8	+1.8
0.0	+1.6	.....	−3.1	−0.5	−5.4	−4.1	−2.1	+2.2	+0.4	+0.2	−0.4	−0.7	+0.7
−2.0	−0.2	.....	−2.0	−0.2	−3.3	−2.9	+0.4	+0.2	−0.2	−1.0	+0.6	+0.5	−0.4
−4.0	−2.0	.....	.....	+1.7	−1.4	−1.6	.....	.....	.....	−2.0	+1.7	+1.7	−1.6

M0

M	4071 77	4455 62	4455 94	4247 50	4258 60	4202 07	4455 82	4455 89	4482 94	4489 94	4494 96
+2.0	+3.6	−0.2	+1.8	.....	−5.5	+3.6	+1.6	+3.3	....	−2.2	+2.3
0.0	+1.9	−1.7	0.0	−6.0	−4.1	+1.2	0.0	+1.8	+0.2	−0.6	+0.4
−2.0	−0.2	.....	+1.1	−3.9	−1.5	−0.9	−1.0	+0.2	+1.8	+1.3	−1.8
−4.0	−2.0	.....	+1.9	−2.3	+1.0	−3.0	−2.0	−2.9	+3.4	+3.4	−3.2

M5

M	4071 77	4455 94	4247 50	4258 60	4202 07	4455 82	4455 89	4482 94	4489 94	4494 96
2.0	+3.5	.....	.....	−6.7	+3.4	.....	+1.8	.....	−1.7	+1.9
0.0	+1.6	0.0	−6.0	−4.4	+1.2	+1.2	−0.1	+0.8	0.0	−0.8
−2.0	+0.6	+1.6	−4.2	−1.2	−0.8	−0.5	−1.5	+2.6	+2.0	−3.2
−4.0	−2.9	+2.8	−2.6	+1.2	−2.9	−2.4	−3.0	+4.4	+4.4	.....

F0

M	4071 77	4215 50	4271 90	4247 50	4162 68
7.0	+ 8.8	.....	.....	.....	.....
5.0	+ 3.5	−1.5	+ 1.5	−3.7	−10.0
3.0	− 1.8	+1.8	− 3.0	−1.0	− 4.0
1.0	− 5.7	+4.8	− 5.6	+1.7	+ 1.7
−1.0	− 9.6	+8.0	− 8.1	+4.5	+ 7.3
−3.0	−13.6	.....	−10.1	+7.2	+13.0

F5

M	4071 / 77	4215 / 50	4271 / 90	4247 / 50	4258 / 60	4162 / 68
7.0	+ 9.2	.....	.....	.....	.....	.....
5.0	+ 5.0	−0.5	+6.0	−5.8	−9.6	− 9.8
3.0	+ 0.5	+3.3	+1.6	−3.3	−5.8	− 4.0
1.0	− 3.8	+6.5	−2.1	−0.6	−3.4	+ 1.5
−1.0	− 8.2	+9.3	−4.5	+2.0	−1.0	+ 6.7
−3.0	−12.1	+8.6	−7.0	+4.7	+1.0	+12.0

G0

M	4071 / 77	4215 / 50	4271 / 90	4455 / 62	4247 / 50	4258 / 60	4162 / 68
7.0	+11.0	.....	.....	+5.5	.....	.....	.....
5.0	+ 7.4	0.0	+7.2	+1.7	−9.6	−7.8	−9.5
3.0	+ 3.8	+ 4.4	+4.7	−0.6	−6.6	−5.3	−5.0
1.0	+ 0.2	+ 7.8	+1.9	−2.0	−3.7	−3.6	−3.0
−1.0	− 3.4	+11.0	−1.0	.....	−0.9	−2.0	−1.0
−3.0	− 7.3	+ 8.6	−3.9	.....	+2.0	−0.4	+4.0

G5

M	4071 / 77	4215 / 50	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4489 / 94	4494 / 96	4455 / 89
7.0	+13.2	− 5.3	+4.8	+9.2	.....	.....	−16.0	.....	.....	.....	.....
5.0	+ 9.6	+ 1.0	+0.6	+6.2	−14.7	−8.8	−11.9	.....	.....	.....	.....
3.0	+ 6.7	+ 4.5	−2.1	+3.0	−11.0	−6.3	− 9.0	+13.0	−10.8	+ 9.8	+15.0
1.0	+ 3.2	+ 7.6	−3.7	0.0	− 7.5	−4.5	− 7.0	+ 7.8	− 8.2	+5.4	+ 9.2
−1.0	− 0.3	+11.0	.....	+2.6	− 4.0	−2.8	− 2.6	+ 3.0	− 4.8	+1.2	+ 4.4
−3.0	− 3.8	+ 8.2	.....	+5.2	− 0.2	−1.2	+ 3.0	− 2.0	0.0	−3.8	− 0.8

K0

M	4071 77	4215 50	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96
8.0	.....	−7.5	+7.0	+10.5	.....	.....	.....	.....	.....	.....	.....	.....
6.0	+13.3	−2.0	+1.6	+ 7.4	−18.1	−11.7	−13.8	.....	+9.0	.....	.....	.....
4.0	+10.0	+1.2	−1.9	+ 4.3	−15.3	− 9.5	−10.5	.....	+6.9	+12.7	−12.0	+11.2
2.0	+ 6.7	+4.0	−4.2	+ 1.3	−12.4	− 7.4	− 8.3	+9.7	+4.4	+ 8.8	− 9.5	+ 7.5
0.0	+ 3.5	+6.5	−5.8	− 0.0	− 9.4	− 5.4	− 6.0	+5.8	+2.2	+ 5.3	− 6.6	+ 4.2
−2.0	+ 0.3	.....	.....	+ 2.0	− 6.6	− 3.0	− 3.3	+1.2	−0.1	+ 1.6	− 2.8	+ 0.0
−4.0	− 2.8	.....	.....	+ 4.3	− 3.6	− 0.6	− 0.5	−3.2	−2.7	− 3.2	+ 3.3	− 3.4

K5

M	4071 77	4215 50	4455 62	4455 94	4258 60	4202 07	4455 82	4455 89	4489 94	4494 96
8.0	.....	−5.7	+7.2	+9.2	.....	.....	+8.3	.....	−1.5	+ 3.0
6.0	.....	−1.4	+1.0	+6.2	.....	.....	+6.4	+13.0	−9.0	+11.0
4.0	+10.8	+1.3	−2.5	+3.0	.....	.....	+4.6	+ 9.7	?	?
2.0	+ 7.0	+3.0	−5.0	0.0	.....	.....	+2.7	+ 6.5	−9.5	+ 7.4
0.0	+ 3.4	+4.7	?	?	−6.5	+5.0	+0.8	+ 3.5	−6.6	+ 4.0
−2.0	− 0.2	?	?	?	−3.4	+1.2	−1.3	0.0	−2.8	− 0.4
−4.0	− 4.2	?	.....	.....	−0.5	−3.2	−3.6	− 4.4	+3.2	− 4.2

M0

M	4071 77	4258 60	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94
2.0	+7.6	−10.6	+7.2	+1.6	+5.6	−6.5	+4.3	−3.2
0.0	+3.2	− 6.4	+3.2	−0.7	+2.2	−3.0	+0.7	0.0
−2.0	−1.4	− 2.0	−0.8	−2.9	−1.8	+1.8	−4.0	+3.5
−4.0	−5.8	+3.0	−5.0	−5.3	−6.0	+7.3	−8.0	+6.7

M5

M	4071 77	4258 60	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94
2.0	+10.0	.....	+5.0	+1.5	+5.6	− 1.8	+ 1.3	− 6.0
0.0	+ 3.0	−6.6	0.0	−0.8	+2.1	+ 1.8	− 2.8	0.0
−2.0	− 3.7	−2.0	− 4.6	−3.0	−1.8	+ 7.5	− 7.2	+ 6.0
−4.0	−10.0	+2.6	−10.0	−5.4	−6.0	+11.5	−12.0	+11.5

There were a few stars, such as α Orionis, α Scorpii and α Herculis that we felt reasonably sure were real giants both on account of their measured parallaxes and because their proper motion indicated great distances. They showed all the lines on which we placed dependence in the K-type, indicative of a very giant character.

We computed the parallax to be expected for each star according to the formula

$$\pi = \frac{\mu}{(.119 V_0^2 + 17.82 \sin^2 d)^{\frac{1}{2}}}$$

The absolute magnitudes derived from this formula were plotted against the step differences measured for the lines which held good in the K-type and which gave every indication of continuing to be of service in later types. It was quite to be expected that these plots would be very discordant on account of the great uncertainties in the assigned magnitudes but nevertheless they did seem to be in accord with a continuation of the lines used in the K-types. Naturally the slope of the curves was somewhat uncertain and we adopted as preliminary practically the same slope as existed in the earlier types and drew the curve so that the absolute magnitudes were represented in the mean. We read off preliminary absolute magnitudes from these curves. It was very satisfactory to find that the accordance between the lines was good. We went through several approximations, first obtaining a set of absolute magnitudes and then replotting curves, trying varying degrees of slope so as to produce on the one hand as good accordance as possible and still have a set of curves which joined on to and was in agreement with the curves already obtained for the K-type.

VII. The Division of the Stars into Groups and the Determination of the Mean Absolute Magnitudes of the Stars in the Groups

There are several ways of deriving the mean absolute magnitude of a group of stars. The various methods necessarily make use of either the trigonometric parallax or the proper motion. None of the methods are entirely satisfactory because the errors, both

accidental and systematic, which are inherent in the observations together with the hypothesis of random motion which must be made, introduce errors which are difficult to evaluate.

Suppose we have a group of N stars for all of which we have radial velocities, proper motions and trigonometric parallaxes. Let

π_c = The ratio circumference to diameter
π = The true parallax
π_0 = The measured trigonometric parallax
ϵ_0 = $\pi - \pi_0$
Mπ = The true absolute magnitude, defined as the apparent magnitude at a distance corresponding to a parallax 0".1, so that
$$M\pi = m + 5 + 5 \log \pi$$
m = The apparent visual magnitude on the Harvard system
π_M = The parallax of a star computed from an absolute magnitude
Mπ_0 = The absolute magnitude computed from a measured parallax
V_0 = The radial velocity of a star corrected for solar motion

Trigonometric Parallaxes (First Method)

Suppose the N stars have the same M and π and therefore the same m. The observed values of π, if there are no systematic errors, will cluster about π some being less and some greater. Let the observed distribution of the errors follow the law of propagation of error with a probable error ρ. The number of errors lying between x and $x+dx$ is given by

$$N \frac{h}{\sqrt{\pi_c}} e^{-h^2x^2} dx$$

where $h = \dfrac{.4739}{\rho}$.

For these stars, the observed π_0 is $\pi + x$ and

$$M\pi_0 = 5 + m + 5 \log(\pi + x).$$

Hence the average observed absolute magnitude will be given by

$$\frac{1}{N} \int_{-\infty}^{+\infty} N(5 + m + 5 \log \overline{\pi + x}) e^{-h^2x^2} \frac{h}{\sqrt{\pi_c}} dx.$$

This reduces to

$$5 + m + 5 \log \pi + \frac{5h}{\sqrt{\pi_c}} \int_{-\infty}^{+\infty} \log \left(1 + \frac{x}{\pi}\right) e^{-h^2x^2} dx.$$

The correction to the computed value of M is

$$-\frac{5h}{\sqrt{\pi_c}}\int_{-\infty}^{+\infty}\log\left(1+\frac{x}{\pi}\right)e^{-h^2x^2}\,dx,$$

$$\text{or}\quad -\frac{5h}{\sqrt{\pi_c}}\int_{o}^{\infty}\frac{\log\left(1+\frac{x}{\pi}\right)+\log\left(1-\frac{x}{\pi}\right)}{10^{(h^2x^2)\,.4343}}\,dx.$$

This integral is always positive showing that the absolute magnitude derived in this way will be too small or that the stars will be computed more giantish than they really are.

To obtain the numerical value of the integral we may plot the curves

$$y=\frac{5h}{\sqrt{\pi_c}}\,\frac{\log\left(1+\frac{x}{\pi}\right)+\log\left(1-\frac{x}{\pi}\right)}{10^{(h^2x^2)\,.4343}}$$

for various values of h and π (cf. Fig. 9).

Each curve is asymptotic to a line whose abscissae is equal to the parallax of the group for which the curve is drawn. For the curve with the smallest ordinate at maximum, for which $\pi=''.100$ and $\rho=.015$ nearly all the errors are less than the parallax for the group and the correction which must be applied can be measured from the area to about .06 of a magnitude if we neglect errors greater than $''.093$ in π. In practice errors half this size very seldom occur. It must not be forgotten, however, that among measured parallaxes positive errors are more likely to be present than negative ones. The extent to which this tendency is present in a group is quite unknown but it probably has a much larger effect than the one just calculated and it will operate in the opposite way.

The second curve for which $\pi=''.040$ has been computed on a basis of a probable error in the parallaxes $''.010$. The correction to π is less than 0.2 if we neglect errors greater than $''.036$. A considerable percentage of the errors would be greater than $''.036$ were they distributed according to the laws of error. It seemed to us that in both these groups of stars the neglected negative errors would more than counterbalance our computed corrections

and we have accepted the absolute magnitude computed for the groups by this method without alteration. The foregoing considerations have been derived for a group of stars all of the same m and π but they hold equally true for a group of stars where this condition is not demanded.

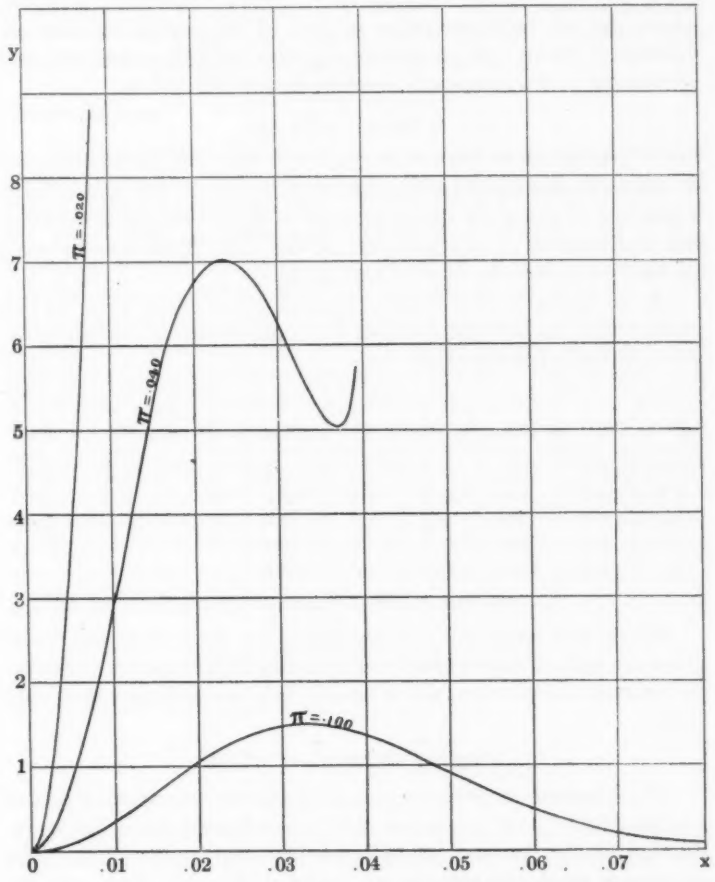


FIG. 9. The Function $y = \frac{5h}{\sqrt{\pi}} \cdot \frac{log\,(1 + x/\pi) + log\,(1 - x/\pi)}{10^{h1\,x2.4\pi3}}$

Trigonometric Parallaxes (Second Method)

Instead of computing the absolute magnitude corresponding to each star, we may take the mean of the observed parallaxes first and then derive

$$\overline{M\pi_0} = 5 + \bar{m} + 5 \log \bar{\pi}_0$$

where the bar indicates mean values. This method has the advantage of being able to include negative parallaxes and the only correction to the computed absolute magnitude will be

$$\overline{5 \log \pi_0} - 5 \log \bar{\pi}_0.$$

For a large group of stars we may assume that the accidental error in the measured parallaxes vanish so that $\bar{\pi}_0 = \bar{\pi}$. We would be in a position to calculate the magnitude of the correction if we knew the distribution of the numbers of the true parallaxes between various limits for the stars in the group.

As an example we will take the 39th group of our list. In this group there are thirteen stars whose approximate M, m and π_M are given in the following table.

M	m	π_M	M	m	π_M	M	m	π_M
0.9	4.6	.018	0.7	4.4	.018	0.3	5.6	.009
0.8	4.7	.016	0.5	4.5	.016	0.6	5.9	.009
1.1	1.1	.100	0.2	4.1	.016	0.3	4.9	.012
0.7	5.9	.009	0.3	3.0	.029	.....	.....	.....
0.5	4.2	.018	0.5	5.5	.010	.....	.....	.....

We do not know the true parallaxes for these stars but those given are approximate values and assuming that these are sufficient to compute a correction, which usually will be small, we can at once derive

$$\overline{5 \log \pi_M} - 5 \log \bar{\pi}_M = -0.60.$$

The absolute magnitudes obtained by the second method are too dwarfish. The correction 0.60 arises largely from the introduction of the one star whose apparent magnitude is 1.1. The correction would be reduced to -0.14 if this star were omitted We see, therefore, that the mean M computed by this method

will be very good if we include stars in one group with reasonably small dispersion in M and m. The true mean absolute magnitude of the group should lie between the values found by the first and second methods provided one can neglect the general tendency to measure trigonometric parallaxes too large. Both methods, however, are best applicable to stars of fairly well determined parallax. The proper motions of the stars must be relied upon for the mean parallax of the most distant stars.

Proper Motions

The first method that occurred to us to use was that developed by Kapteyn giving the mean parallax as a function of the apparent magnitude and proper motion. This method has been elaborated by Van Rhijn in Groningen Publications, Number 34. The objection we see to the method, however, is that the stars are divided into groups on the basis of the proper motions which are themselves to be used for getting the mean parallaxes. Moreover, when we select a list of small proper motion stars we may pick out those that are moving most rapidly in the line of sight. That these tendencies are operative is shown from Van Rhijn's work itself when he finds that the mean parallax of stars of zero proper motion is not zero. It seemed to us inevitable that the method would make the giant stars too giantish. The objection we have urged against taking the proper motions as a basis of division holds, though possibly with diminished force, when the grouping is based on a particular component of the proper motion.

We have used the two well known formulae

$$\pi = 0.237\ \frac{v \sin \lambda}{\sin^2 \lambda},\quad \pi = 4.738\ \frac{\tau}{V_0}$$

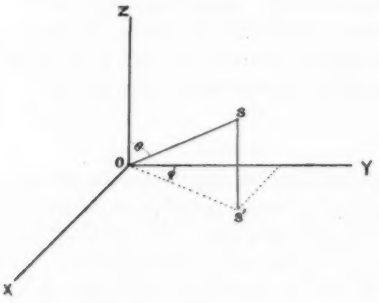
and a third formula

$$\pi = \frac{\mu}{(17.8 \sin^2\lambda + .119 V_0^2)^{\frac{1}{2}}}$$

which we will now develop.

Suppose we have N stars at the point α and δ in the sky whose distance from the apex of the sun's way is λ. Suppose also that all these stars are at the same distance, parallax π, and further let the space velocity of all the stars be the same, Vs

Suppose the stars in regard to direction of motion are moving at random, then the N vectors representing the space velocities of the stars will have their ends uniformly distributed over a sphere.



At the point O draw three rectangular axes, OZ in the direction of the line of sight, OY in the direction of the anti-apex and OX, perpendicular to these two. The proper motion component caused by the velocity of the sun through space lies along the line OY. Let K represent it.

$$K = .2111\ V\odot\pi \sin \lambda$$

K is expressed in seconds of arc per year if $V\odot$, which is the velocity of the sun is in kilometres per second.

Let OS represent the peculiar velocity of the star. OS' is the component which contributes to the observed proper motion. Let

$$L = .2111\ Vs\ .\ \pi$$

then the proper motion component due to the space velocity Vs of the star equals $L \sin \theta$. The total observed proper motion is given by

$$\mu^2 = (K^2 + L^2 \sin^2\theta + 2KL \sin \theta \cos \phi)\pi^2.$$

For stars for which θ is constant we obtain the average value of μ to be given by

$$\bar{\mu} = \frac{1}{\pi} \int_o^\pi (K^2 + L^2 \sin^2\theta + 2KL \sin \theta \cos \phi)^{\frac{1}{2}}\, d\phi$$

and if we are content to take the mean of the square of μ we obtain

$$\overline{\mu^2} = \frac{1}{\pi^2} (K^2 + L^2 \sin^2 \theta).$$

The number of stars which will have a value θ lying between θ and $\theta+d\theta$ is given by

$$\frac{N}{2}\sin\theta\, d\theta$$

and since in our formula for mean values the angle enters as the square we have the total number of stars for which θ is alike to be $N \sin\theta\, d\theta$. The average value of μ^2 for all the stars is given by

$$\begin{aligned}\overline{\mu^2} &= \int_o^{\frac{\pi}{2}} (K^2 \sin\theta + L^2 \sin^3\theta)\, d\theta \\ &= K^2 + \tfrac{2}{3}L^2 \\ &= (.2111\ V\odot)^2 \sin^2\lambda\pi^2 + \tfrac{2}{3}(.2111\ Vs)^2\pi^2.\end{aligned}$$

Letting $V\odot = 20km$ and putting $Vs = 2V_0$ we get

$$\overline{\mu^2} = (17.8 \sin^2\lambda + .119\ V_0^2)\pi^2.$$

We think that any of the three formulae will give good results if used for groups of stars which do not favour either large or small proper motions. The first method we considered was the trigonometric parallaxes. These are perfectly satisfactory for the nearer stars. In the case of the more distant stars the large accidental errors tend to throw together stars of widely different absolute magnitudes and in addition it tends to form a group of fictitiously giant stars. This difficulty could be almost entirely overcome if we had *two* methods of dividing the stars into groups each of which was independent of the proper motion and also of each other, because the chances that any particular star would be accidentally measured with a small parallax in both systems could be neglected. We have assumed that the spectroscopic parallaxes are sufficient for this purpose and accordingly have used as absolute magnitudes the means of the Mount Wilson (spectroscopic and those derived) from the trigonometric parallaxes for dividing the giant stars into groups. The mean parallax for each group was computed by each of the three formulae given above and the mean taken and then the mean absolute magnitude computed by

$$\overline{M} = m + 5 + 5 \log \overline{\pi}.$$

We have assumed that the Boss proper motions when corrected according to the formula given on page XXVIII of Boss' cata-

logue are sensibly free from systematic error. If it is found later that the correction ″.013 cos δ, which has been suggested, must be applied the results may be altered. In the detailed publication we are investigating the effect of this correction. It seemed to us best to omit it altogether. We have assumed also that for our groups of stars the motion could be considered at random when allowance was made for the effect of the solar motion for which the constants

$$\alpha = 270°, \quad \delta = 30°, \quad V\odot = 20 \text{ km.}$$

were taken. We neglected the effect of the stream motions.

VIII. Results for the K-type and M-type Stars

As the main purpose of the paper is to give the results for the later type stars, we present the results for stars of type F and G very briefly. Table 5 below gives a summary of the mean absolute magnitudes we have derived for our various groups in types A5-K9. The fifth column headed "M adopted", shows the absolute magnitudes we used in plotting our results from the various lines. The seventh column contains the values derived from the trigonometric parallax by the formula

$$\bar{M} = \bar{m} + 5 + 5 \log \bar{\pi}_0.$$

Reasons were given in section VII for believing that the true absolute magnitude should lie between the values given in columns five and seven and as the two columns are in fair agreement the true absolute magnitude is confined within narrow limits. The spectroscopic absolute magnitudes as derived by both Young and Harper are given and the mean values for the various groups are in satisfactory agreement with the computed ones and with those obtained at Mount Wilson also. The gathering together of the results from individual stars into groups is not, however, a very good way of illustrating comparative values for it glosses over individual discordances.

Figs. 10 and 11 show a plot of the absolute magnitudes for the F and G stars as obtained at Victoria and Mount Wilson. If the agreement were perfect all the points in these diagrams would lie on a line passing through the point 0.0 and inclined at an angle of 45 degrees. With the exception of the giant G stars between

TABLE 5

	No. of Stars	Mean m	Type	M Adopted	Mean Trig. π	M from Trig. π	Mt. W. M	Young M	Harper M
1	6	4.02	A7	0.60	.012	0.60	0.75	1.00	1.37
2	11	4.65	A7	2.01	.026	1.70	1.44	1.93	1.98
3	8	4.41	A9	2.69	.050	2.89	1.90	2.46	2.24
4	6	3.85	F4	−0.70	.011	−1.00	−1.00	−0.23	−0.13
5	8	3.75	F7	−2.95	.013	−0.70	−1.76	−1.56	−1.61
6	4	4.00	G0	−2.48	.....	.....	−3.80	−2.25	−2.16
7	7	5.23	G2	−2.99	.007	−0.50	−2.60	−3.17	−2.73
8	8	3.85	G3	−0.46	.014	−0.30	−0.15	+0.91	+0.68
9	6	5.00	F4	2.60	.002	−3.50	+1.00	+0.93	+1.07
10	8	4.11	F4	2.36	.035	+1.80	+2.00	+1.61	+1.71
11	7	5.27	F3	2.98	.023	+2.00	+2.64	+2.53	+2.77
12	10	5.30	F4	2.58	.036	+3.10	+2.76	+2.90	+3.00
13	7	4.96	F4	3.23	.052	+3.50	+3.20	+3.46	+3.41
14	8	4.70	F4	4.18	.085	+4.30	+3.40	3.68	+3.46
15	8	6.10	F5	4.60	.058	4.90	3.76	3.96	+3.70
16	10	4.97	F7	3.33	.040	3.97	3.21	3.57	+3.35
17	11	5.15	F8	3.97	.044	3.40	3.54	3.91	+3.87
18	8	5.38	F7	3.75	.054	4.00	3.58	3.84	+4.00
19	11	5.60	F8	4.34	.058	4.40	3.83	4.16	+4.06
20	9	5.96	F8	4.81	.062	4.80	3.95	4.27	+4.20
21	7	5.27	F8	5.17	.106	5.14	4.90	5.03	+4.53
22	10	4.76	G3	2.97	.029	2.00	1.82	1.96	+2.10
23	10	5.32	G2	3.87	.055	4.00	3.82	3.76	+3.48
24	11	5.20	G1	4.44	.072	4.47	4.40	4.67	+4.36
25	10	5.50	G1	4.77	.078	4.96	4.70	4.68	+4.66
26	8	6.26	G3	5.75	.081	5.80	5.30	5.00	+4.84
27	9	3.70	G6	−0.90	.016	−0.34	−0.79	−0.25	+0.08
28	10	4.53	G6	1.43	.017	+0.60	0.11	+0.77	+0.91
29	22	4.27	G7	0.15	.017	+0.40	0.68	+1.00	+1.28
30	19	4.72	G7	1.09	.032	+2.23	0.11	+1.46	+1.58
31	8	5.05	G7	3.32	.047	+3.42	2.21	+2.10	+2.04
32	8	5.50	G7	5.46	.055	+4.20	4.34	+4.30	+3.42
33	9	5.77	G7	5.09	.079	+5.26	5.10	+4.88	+5.11
34	7	5.46	G8	6.23	.159	+6.48	5.86	+5.90	+5.74
35	6	4.15	K1	−4.14	.008	−1.45	−2.50	−3.35	−2.93
36	18	3.67	K3	−1.08	.002	−4.7	0.34	−0.20	−0.03
37	33	4.15	K2	0.52	.022	+0.87	0.62	+0.80	+0.88
38									
39	13	4.49	K6	0.60	.026	+1.54	0.57	−0.10	+0.05
40	12	5.02	K1	2.04	.038	+2.90	1.42	1.77	+1.28
41	7	5.43	K1	3.79	.034	+3.05	3.10	2.04	+2.20
42	13	5.77	K1	5.98	.124	+6.24	5.87	5.71	+5.63
43	8	5.44	K6	7.40	.203	+7.00	7.58	7.43	+7.55

Table giving the Mean Absolute Magnitudes derived for the various groups of stars, types A5-K9.

logue are sensibly free from systematic error. If it is found later that the correction ".013 cos δ, which has been suggested, must be applied the results may be altered. In the detailed publication we are investigating the effect of this correction. It seemed to us best to omit it altogether. We have assumed also that for our groups of stars the motion could be considered at random when allowance was made for the effect of the solar motion for which the constants

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VIII. Results for the K-type and M-type Stars

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3	8	4.41	A9	2.69	.050	2.89	1.90	2.46	2.24
4	6	3.85	F4	−0.70	.011	−1.00	−1.00	−0.23	−0.13
5	8	3.75	F7	−2.95	.013	−0.70	−1.76	−1.56	−1.61
6	4	4.00	G0	−2.48	.....	.....	−3.80	−2.25	−2.16
7	7	5.23	G2	−2.99	.007	−0.50	−2.60	−3.17	−2.73
8	8	3.85	G3	−0.46	.014	−0.30	−0.15	+0.91	+0.68
9	6	5.00	F4	2.60	.002	−3.50	+1.00	+0.93	+1.07
10	8	4.11	F4	2.36	.035	+1.80	+2.00	+1.61	+1.71
11	7	5.27	F3	2.98	.023	+2.00	+2.64	+2.53	+2.77
12	10	5.30	F4	2.58	.036	+3.10	+2.76	+2.90	+3.00
13	7	4.96	F4	3.23	.052	+3.50	+3.20	+3.46	+3.41
14	8	4.70	F4	4.18	.085	+4.30	+3.40	3.68	+3.46
15	8	6.10	F5	4.60	.058	4.90	3.76	3.96	+3.70
16	10	4.97	F7	3.33	.040	3.97	3.21	3.57	+3.35
17	11	5.15	F8	3.97	.044	3.40	3.54	3.91	+3.87
18	8	5.38	F7	3.75	.054	4.00	3.58	3.84	+4.00
19	11	5.60	F8	4.34	.058	4.40	3.83	4.16	+4.06
20	9	5.96	F8	4.81	.062	4.80	3.95	4.27	+4.20
21	7	5.27	F8	5.17	.106	5.14	4.90	5.03	+4.53
22	10	4.76	G3	2.97	.029	2.00	1.82	1.96	+2.10
23	10	5.32	G2	3.87	.055	4.00	3.82	3.76	+3.48
24	11	5.20	G1	4.44	.072	4.47	4.40	4.67	+4.36
25	10	5.50	G1	4.77	.078	4.96	4.70	4.68	+4.66
26	8	6.26	G3	5.75	.081	5.80	5.30	5.00	+4.84
27	9	3.70	G6	−0.90	.016	−0.34	−0.79	−0.25	+0.08
28	10	4.53	G6	1.43	.017	+0.60	0.11	+0.77	+0.91
29	22	4.27	G7	0.15	.017	+0.40	0.68	+1.00	+1.28
30	19	4.72	G7	1.09	.032	+2.23	0.11	+1.46	+1.58
31	8	5.05	G7	3.32	.047	+3.42	2.21	+2.10	+2.04
32	8	5.50	G7	5.46	.055	+4.20	4.34	+4.30	+3.42
33	9	5.77	G7	5.09	.079	+5.26	5.10	+4.88	+5.11
34	7	5.46	G8	6.23	.159	+6.48	5.86	+5.90	+5.74
35	6	4.15	K1	−4.14	.008	−1.45	−2.50	−3.35	−2.93
36	18	3.67	K3	−1.08	.002	−4.7	0.34	−0.20	−0.03
37	33	4.15	K2	0.52	.022	+0.87	0.62	+0.80	+0.88
38									
39	13	4.49	K6	0.60	.026	+1.54	0.57	−0.10	+0.05
40	12	5.02	K1	2.04	.038	+2.90	1.42	1.77	+1.28
41	7	5.43	K1	3.79	.034	+3.05	3.10	2.04	+2.20
42	13	5.77	K1	5.98	.124	+6.24	5.87	5.71	+5.63
43	8	5.44	K6	7.40	.203	+7.00	7.58	7.43	+7.55

Table giving the Mean Absolute Magnitudes derived for the various groups of stars, types A5-K9.

absolute magnitudes 0 and +2, where our values seem to be a little more positive, the general agreement is very good but the accidental differences are quite large. It would be expected that the Victoria values would have much the smaller accidental error of measurement because of the greater number of lines used. We reserve a critical discussion on this point and on the extent of the systematic errors for our more detailed publication.

The most giantish stars which appear in both these diagrams and those drawn for the later types shown in Figs. 12, 13, 14 are listed by Adams as c-stars. There does not seem to be any sharp line of distinction in our absolute magnitudes nor can we see any in the spectra. Our reduction curves for these stars join on to our other stars satisfactorily. As was pointed out in a dis-

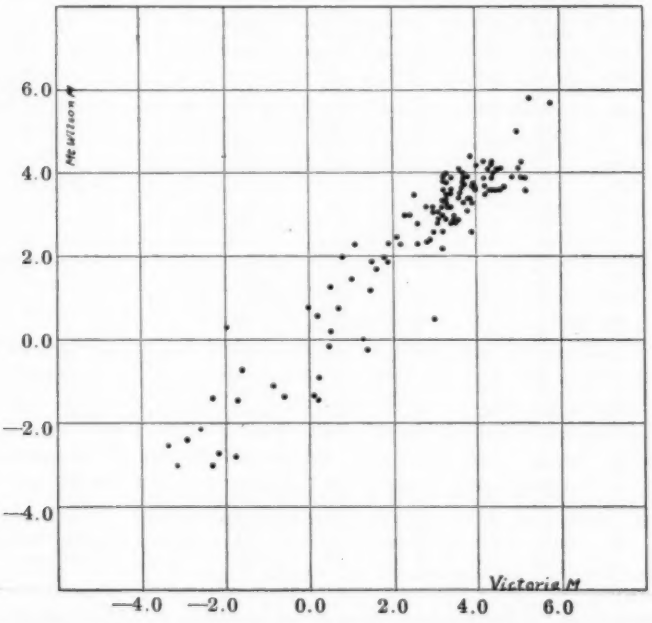

FIG. 10. Comparison of Victoria and Mount Wilson Absolute Magnitudes in Types F0-F9. Ordinates are Mount Wilson Values, Abscissae are Victoria values.

cussion of the lines used for getting the absolute magnitudes some of the ratios were not single valued in relation to step value but this does not affect the continuity of the variation. Our values of the absolute magnitude for those c-stars which are Cepheids and have had their period of light variation determined are in better agreement with the period luminosity relation given for these stars by Shapley than are the Mount Wilson ones and we will discuss this point more fully later.

Table 6 gives the absolute magnitudes we have derived for stars of types K0 to M8. The stars in this list are those used in deriving our reduction curves and most of them are found in the Mount Wilson list of 1645 parallaxes. In addition to these stars we have among the stars observed for radial velocity about as

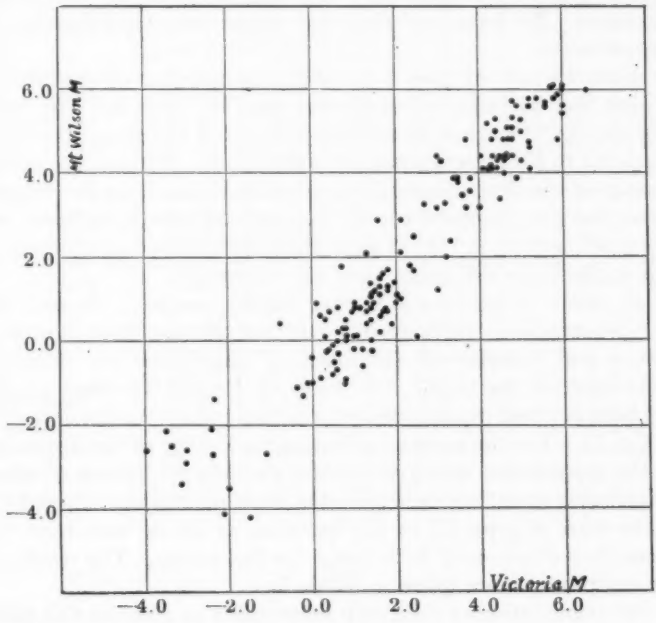

FIG. 11. Comparison of Victoria and Mount Wilson Absolute Magnitudes in Types G0-G9.

many more which will also be available for discussion. The present report, however, deals with the stars given in Table 6. The list includes practically all the stars that have been observed in common by the two observatories and are therefore the ones suited for making a comparison of the results. The proper motion given in column seven is the corrected Boss value and the column headed V_0 gives the radial velocity of the star corrected for solar motion. The absolute magnitude derived at Victoria is given under the heading Vict. M and the spectroscopic parallax follows. The rest of the table is self explanatory.

Results are given for stars up to and including type M8. We do not think that the absolute magnitudes for the very late M-types are very well determined because there are very few stars and the tables are necessarily less accurate near the end of the sequence. We have excluded stars later than type M6 in our computations.

Figs. 12, 13, 14 give a graphical comparison of the Mount Wilson and Victoria values for the stars in Table 6. The early K's and the M's are in general agreement but the giant stars from types K3 to K9 show a remarkable difference. Whereas we obtain a range of absolute magnitude in these stars of almost five magnitudes they get a range of a little over one. In our original grouping many of the stars in Fig. 13 were distributed in several groups and this masked the difference between the results.

In order to study the matter further we have divided the K-type stars into eight groups and the M-type stars into four groups and recomputed the absolute magnitudes for these by proper-motion methods. The basis of division in these groups has been our own magnitudes, that is lines parallel to the ordinates in Fig. 13. For the purpose of testing the reality of the dispersion in the magnitudes which we obtain the Mount Wilson absolute magnitudes would not be a suitable basis of comparison, at least in the stars of type K3 to K9, because, as can be seen from the curve they obtain very little range for these stars. The results of the computation are given in Table 7.

An examination of the group magnitudes as given in this table shows clearly that when the stars are divided according to our values they reproduce the range indicated by the proper motions

TABLE 6

Boss	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	Mt W. M	Vict. M	Spec. π
		h m	° ′							
31	χPegasi	00 09.4	19 39	4.9	M1	.097	+47.6	0.0	0.0	.010
96	.....	26.2	52 17	5.7	K0	.056	−48.8	0.3	+0.2	.008
132	δAndrom.	34.0	30 19	3.5	K3	.166	+ 7.9	0.8	+1.3	.036
133	54 Pisc.	34.2	20 43	6.1	K1	.595	−32.7	6.2	+5.4	.072
161	57 Pisc.	41.3	14 56	5.6	M6	.064	−26.4	0.4	−1.0	.005
168	ηCass ft.	43.0	57 17	7.4	K6	1.245	.....	8.3	+8.2	.145
171	.....	43.1	4 46	5.8	K4	1.370	−14.2	6.5	+7.0	.174
173	δPisc.	43.5	7 02	4.6	K5	.097	+30.5	0.9	−0.7	.009
259	βAndrom.	01 04.1	35 05	2.4	M0	.218	1.9	0.5	+0.0	.033
313	θCeti	19.0	− 8 42	3.8	K0	.228	+10.1	0.3	+1.0	.028
357	υPersei	31.9	48 07	3.8	K4	.130	+19.1	0.5	+1.5	.034
378	νPisc.	36.2	4 59	4.7	K5	.018	− 5.3	0.8	+0.2	.012
382	107 Pisc.	37.1	19 47	5.3	K1	.735	−37.6	5.8	+6.0	.138
394	.....	40.5	63 22	5.7	K0	.635	+ 7.6	5.6	+6.2	.126
420	55 Androm.	47.3	40 14	5.6	K2	.011	− 5.7	0.5	−0.4	.006
468	γ_1Androm.	57.8	41 51	2.3	K1	.073	−10.5	−0.1	−0.4	.029
477	αArietis	02 01.5	22 59	2.2	K2	.242	−18.5	0.7	+1.2	.063
545	65 Androm.	18.9	49 50	4.9	K7	.032	− 1.7	0.3	+0.2	.012
582	15 Triang.	29.7	34 15	5.6	M3	.062	−15.3	0.3	−0.6	.006
588	Pi II. 123	30.6	6 25	5.9	K7	2.321	+13.1	6.5	+6.8	.151
634	39 Arietis	42.0	28 50	4.6	K1	.199	−19.3	0.0	+1.4	.023
639	ηPersei	43.4	55 29	3.9	K4	.029	+ 0.4	0.4	−2.2	.006
646	17 Persei	45.4	34 39	4.7	K4	.079	+10.5	0.7	−1.4	.006
660	45 Arietis	50.2	17 55	5.9	M8	.019	+38.4	−0.3	−2.0	.003
669	.....	52.8	79 01	5.7	M1	.039	−32.4	.....	−0.5	.006
691	αCeti	57.1	3 42	2.8	M1	.080	−37.3	−0.1	−0.4	.023
698	ρPersei	58.8	38 27	3.7	M6	.175	+25.4	−0.8	−2.0	.007
746	.....	03 12.5	33 51	4.9	K2	.016	− 1.7	0.2	−0.8	.007
795	σPersei	23.5	47 39	4.6	K4	.021	+15.1	0.4	−0.4	.010
814	ϵErid.	28.2	− 9 48	3.8	K1	.967	+ 0.5	6.0	+6.2	.302
826	D.C. 2070	33.5	62 54	5.3	M5	.020	−24.4	−0.5	−1.0	.006
936	37 Tauri	58.8	21 49	4.5	K0	.116	− 0.8	0.8	+1.2	.022
952	43 Tauri	04 03.3	19 21	5.7	K1	.117	+10.6	1.4	+0.9	.011

TABLE 6—Cont.

Boss	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	Mt W. M	Vict. M	Spec. π
		h m	° ′							
984	40 Erid.	04 10.7	− 7 49	4.5	K1	4.082	−58.2	6.2	+6.1	.209
1077	αTauri	30.2	16 19	1.1	K8	.205	+42.6	1.1	+0.5	.076
1128	.....	42.7	63 20	5.8	M4	.112	−33.9	0.5	−0.2	.006
1167	ιAurigae	50.5	33 00	2.9	K4	.029	+10.1	0.0	−0.8	.018
1335	119 Tauri	05 26.3	18 32	4.7	M4	.015	+10.9	.....	−3.2	.003
1385	.....	33.2	53 26	6.4	K2	.510	− 2.2	5.7	+5.6	.069
1439	υAurigae	44.2	37 16	5.0	M1	.052	+32.5	0.0	0.0	.010
1442	νAurigae	44.6	39 0	74.2	K0	.007	+ 2.5	0.2	+1.3	.027
1468	αOrionis	49.8	7 23	0.9	M1	.032	+ 5.5	−3.8	−4.2	.010
1479	πAurigae	52.5	45 56	4.6	M4	.012	− 3.5	−0.8	−2.2	.004
1561	ηGemin.	06 08.8	22 32	3.7	M2	.062	+ 7.9	−0.5	−1.8	.008
1604	μGemin.	16.9	22 34	3.2	M3	.130	+43.2	−0.8	−0.8	.016
1606	46 Aurigae	17.2	49 20	5.1	K2	.014	− 6.3	−3.6	−5.2	.001
1643	.....	24.9	78 04	5.9	K5	.018	− 7.7	0.7	−0.2	.006
1840	τGemin.	07 04.8	30 25	4.5	K3	.051	+13.2	0.5	+1.0	.020
1846	.....	05.6	51 36	5.7	M4	.019	−51.7	0.1	−1.0	.005
1854	18 Lyncis	07.2	59 49	5.3	K1	.271	+23.3	1.3	+2.5	.028
1868	53 Gemin.	09.7	28 05	5.9	M0	.019	+12.4	−0.2	−0.6	.005
1871	.....	10.1	82 36	5.1	M5	.044	+19.0	.....	−1.2	.006
1919	66 Aurigae	17.2	40 52	5.3	K0	.023	+16.6	−0.3	−1.0	.006
1987	υGemin.	29.8	27 07	4.2	K7	.119	−29.6	0.5	+0.5	.018
2023	σGemin.	37.0	29 07	4.3	K1	.247	+36.9	2.6	+2.0	.034
2049	πGemin.	41.1	33 40	5.3	M0	.039	−20.5	0.3	−1.4	.005
2130	.....	57.1	02 36	4.5	K2	.106	+56.8	1.1	0.4	.015
2195	βCancri	08 11.1	09 30	3.8	K4	.072	+10.5	0.4	−0.6	.013
2208	31 Lyncis	16.0	43 31	4.4	K6	.106	+21.3	0.7	+0.1	.014
2290	πUrs. Maj.	31.5	64 40	4.8	K1	.053	+17.4	1.0	+1.7	.024
2336	δCancri	39.0	18 31	4.2	K1	.241	+ 8.2	0.8	+0.6	.019
2380	55 Cancri	46.6	28 43	6.1	K2	.536	+21.3	5.7	+5.6	.080
2411	ρUrs. Maj.	09 53.5	68 01	5.0	M2	.023	+10.9	−0.1	−0.5	.008
2474	.....	08.5	57 10	5.5	M0	.034	−28.8	.....	−0.3	.007
2507	αLyncis	15.0	34 49	3.3	K8	.215	+34.8	0.6	+0.8	.032
2524	κLeonis	18.8	26 37	4.6	K2	.059	+22.9	1.3	+1.1	.020

TABLE 6—Cont.

Boss	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	Mt W. M	Vict. M	Spec. π
		h m	° ′							
2528	.....	09 20.0	17 01	6.3	K0	.076	+ 0.8	2.2	2.4	.016
2533	αHydrae	22.7	− 8 14	2.2	K5	.035	−15.8	0.1	−0.4	.030
2550	λLeonis	26.1	23 25	4.5	K8	.053	+22.6	0.5	−0.5	.010
2556	6 Leonis	26.5	10 09	5.3	K4	.024	+17.6	0.5	−1.4	.005
2578	.....	30.8	31 37	5.7	M2	.042	−25.9	.....	−1.0	.005
2621	.....	40.9	07 10	6.0	M2	.039	− 7.7	0.9	−1.0	.004
2648	μLeonis	47.1	26 29	4.1	K2	.225	+10.5	0.6	+2.0	.038
2656	.....	49.5	73 21	6.0	K1	.078	+ 8.2	0.4	+1.7	.014
2673	.....	53.0	57 18	5.7	M0	.051	−10.7	.....	+0.9	.011
2680	πLeonis	54.9	08 31	4.9	M2	.041	+15.9	−0.9	−0.6	.008
.....	Groom 1618	10 05.3	49 58	6.8	K6	1.451	−27.6	8.3	+7.9	.166
2751	μUrs. Maj.	16.4	42 00	3.2	K5	.083	−19.8	0.7	+0.4	.028
2800	46 Leonis	26.9	14 39	5.7	M2	.040	+30.0	1.0	−1.2	.004
2847	.....	36.6	32 14	6.3	M5	.028	+14.4	.....	−1.6	.003
2865	.....	40.2	57 53	6.5	M2	.079	+ 4.3	1.0	−0.6	.004
2897	.....	46.7	70 23	6.1	K0	.404	+24.7	4.3	+3.6	.032
2899	46 Leo. Min.	47.7	34 45	3.9	K1	.303	+17.8	1.4	+1.8	.038
2910	.....	50.2	34 02	5.2	K1	.112	−22.1	0.7	+0.7	.013
2921	.....	53.9	36 40	6.2	M4	.096	−31.1	1.0	−0.4	.005
3030	86Leonis	11 25.3	18 58	5.7	K0	.076	+25.9	1.1	+0.8	.011
3031	λDraco.	25.5	69 53	4.1	K5	.043	+15.4	0.2	−1.1	.009
3089	νVirg.	40.7	07 05	4.2	M0	.185	+51.0	0.2	−0.5	.011
3213	16 Virg.	12 15.3	03 53	5.1	K0	.304	+37.4	1.6	0.0	.010
3242	γCom. Ber.	22.0	28 49	4.6	K1	.120	+10.2	0.7	+1.3	.022
3326	33 Virg.	41.3	10 06	5.9	K0	.530	+55.8	4.2	+2.8	.024
3367	δVirg.	50.6	03 56	3.7	M4	.475	−12.7	0.3	−0.1	.017
3374	36 Com. Ber.	54.0	17 57	5.0	M0	.033	+ 5.6	0.9	−0.6	.008
3398	40 Com. Ber.	13 01.5	23 09	5.9	M8	.065	+ 1.9	0.2	−2.2	.002
3446	σVirg.	12.6	06 00	5.0	M2	.015	−19.7	0.3	−1.6	.005
3536	83 Urs. Maj.	36.9	55 12	4.8	M0	.025	− 5.2	.....	−0.6	.008
3581	.....	46.7	35 10	6.0	M1	.070	−29.8	0.7	−0.3	.006
3584	.....	47.4	34 57	5.0	M6	.040	−30.1	0.4	−1.0	.006
3589	10 Draco.	48.5	65 13	4.8	M4	.005	+ 2.1	−0.5	−1.2	.006

TABLE 6—Cont.

Boss	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	MtW. M	Vict. M	Spec. π
		h m	° ′							
3631	.....	14 04.6	49 56	5.4	M2	.068	− 0.2	−0.2	−0.9	.006
3658	.....	10.3	42 00	6.2	K3	.120	+10.1	0.7	+2.6	.019
3662	αBootis	11.1	19 42	0.2	K0	2.283	+ 7.1	1.2	+0.2	.100
3717	ρBootis	27.5	30 49	3.8	K3	.148	+ 0.5	0.8	0.0	.017
3736	.....	33.6	18 44	6.0	K1	.093	− 2.4	1.9	0.6	.008
....	C 1972	48.9	19 34	6.0	K0	.485	−27.7	5.9	5.2	.069
3809	βUrs. Min.	51.0	74 34	2.2	K4	.028	+29.8	0.5	−0.6	.028
3816	1 Serpen.	52.4	00 14	5.7	K2	.070	+33.1	1.8	+0.9	.011
3827	.....	56.0	66 20	4.9	M7	.080	+21.5	−0.6	−1.9	.004
3907	6 Serpen.	15 16.0	01 04	5.5	K2	.122	+23.5	1.8	+1.0	.012
3936	ιDraco.	22.7	59 19	3.5	K2	.011	+ 5.2	0.1	+1.6	.042
4001	αSerpen.	39.3	6 44	2.8	K3	.142	+18.6	−0.2	+1.8	.063
4032	κCor. Bor.	47.5	35 59	4.8	K1	.363	− 5.5	1.6	+2.6	.036
4048	.....	50.2	20 36	5.8	K4	.080	−45.2	0.8	−2.2	.003
....	C 2163	16 04.3	06 41	6.0	K1	.760	+11.9	4.4	+3.0	.025
4108	τCor. Bor.	05.3	36 45	4.9	K0	.325	+ 5.8	2.8	+2.2	.029
4134	δOphiuchi	09.1	− 3 26	3.0	K8	.159	− 4.8	0.3	0.0	.025
4169	ξCor. Bor.	18.2	31 07	4.7	K0	.131	− 9.5	0.7	+1.7	.025
4193	αScorpii	23.3	−26 13	1.2	M2	.032	+ 6.5	−2.7	−3.4	.012
4195	.....	23.5	00 52	5.5	K6	.075	+24.2	+0.5	+0.6	.011
4242	.....	36.0	49 07	5.1	M3	.041	−37.7	−0.3	−0.5	.008
4262	.....	40.8	15 56	5.8	M3	.055	− 1.8	0.8	−0.4	.006
4311	54 Herc.	51.0	18 35	5.6	K6	.102	+30.3	0.3	+0.4	.009
4336	32 Ophiuchi	58.6	14 14	5.1	M2	.071	+59.6	−0.1	−0.7	.007
....	C 2277	59.8	47 11	6.7	K0	.856	−27.4	4.1	+5.7	.063
4373	αHerc.	17 10.1	14 30	3.5	M7	.028	−13.6	−2.3	−3.0	.005
4381	πHerc.	11.6	36 55	3.4	K3	.021	− 5.6	0.4	+0.2	.023
4400	.....	15.9	18 10	5.2	M0	.052	−26.9	.....	−1.8	.004
....	C 2333	25.3	67 24	6.3	K0	.536	−22.5	5.9	+5.6	.072
4487	βOphiuchi	38.5	04 37	2.9	K2	.157	+ 6.4	0.6	+1.7	.058
4531	ξDraco.	51.8	56 53	3.9	K3	.126	− 7.2	0.7	+1.8	.038
4535	θHerc.	52.8	37 16	4.0	K1	.008	− 6.6	−0.3	−1.1	.010
4541	γDraco.	54.3	51 30	2.4	K5	.026	− 8.5	0.6	+0.1	.034

TABLE 6—Cont.

Boss	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	Mt W. M	Vict. M	Spec. π
		h m	° ′							
4555	.....	17 57.1	45 31	5.9	K7	.044	+ 9.3	0.6	−0.8	.005
4571	70 Oph. (br)	18 00.4	02 31	4.3	K1	1.132	+10.3	5.8	+5.4	.166
4571	70 Oph. (ft)	00.4	02 31	6.0	K4	1.132	+10.2	7.2	+7.2	.174
4578	.....	01.8	22 13	5.3	M2	.020	− 2.7	.....	−0.8	.006
4606	104 Herc.	08.2	31 22	5.0	M5	.016	+18.6	−0.1	−0.6	.008
4653	.....	19.0	49 04	5.1	M1	.057	+32.6	.....	−0.8	.007
4629	105 Herc.	15.1	24 24	5.5	K2	.019	+ 4.8	0.2	−1.0	.005
4656	109 Herc.	19.4	21 43	3.9	K1	.326	−37.3	1.5	+1.4	.032
4814	R Lyrae	52.3	43 49	4.3	M7	.078	−13.0	−1.4	−2.0	.006
4971	.....	19 22.5	88 59	6.6	M4	.028	+10.8	.....	−1.2	.003
4976	αVulpec.	24.5	24 28	4.6	M0	.168	−67.0	+0.1	−0.2	.011
4986	β^1Cygni	26.7	27 45	3.2	K0	.010	− 4.1	+0.8	−0.2	.021
4995	μAquilae	29.2	07 10	4.6	K4	.265	− 6.7	0.7	+1.6	.025
5047	γAquilae	41.5	10 22	2.8	K3	.018	+15.1	0.3	−0.6	.021
5052	δSagittae	42.9	18 17	3.8	M0	.009	+21.0	0.2	−1.2	.010
5075	20 Cygni	48.1	52 45	5.2	K4	.072	− 3.0	0.2	+1.8	.021
5118	γSagittae	54.3	19 13	3.7	K8	.065	−16.1	0.5	+0.8	.026
5154	.....	20 02.4	76 13	6.4	M2	.059	−56.7	.....	−0.9	.004
5271	.....	28.2	48 53	5.6	M1	.041	−49.4	.....	−1.0	.005
....	C 2667	29.3	41 32	7.0	K0	.475	+ 5.8	6.0	+5.6	.053
5335	γ^2Delp.	42.0	15 46	4.5	K1	.207	+ 9.1	1.1	+2.7	.044
5431	ξCygni	21 01.3	43 32	3.9	K4	.011	− 3.3	−2.9	−2.1	.006
5433	61^1 Cygni	02.4	38 15	5.6	K7	5.267	−49.2	8.3	+8.1	.316
5433	61^2 Cygni	02.4	38 15	6.3	K8	5.155	−47.7	8.3	+8.2	.240
5489	1 Pegasi	17.5	19 23	4.2	K0	.120	−61.9	1.4	+1.9	.034
5522	2 Pegasi	25.5	23 12	4.8	M0	.021	− 4.7	0.6	+0.2	.012
5567	.....	36.3	42 49	5.4	M0	.056	−15.1	.....	0.0	.008
5584	εPegasi	39.3	09 25	2.5	K2	.028	+16.7	−0.3	−1.8	.014
5593	μCephei	40.4	58 19	4.5	M2	.005	+36.2	0.3	−4.9	.001
5619	.....	46.4	60 49	6.4	M1	.019	− 6.3	.....	0.0	.005
5674	νPegasi	22 00.6	04 34	4.9	K9	.146	− 6.3	0.3	+0.2	.012
5678	.....	00.8	62 38	5.5	M4	.053	+ 6.5	.....	−1.5	.004
5714	ζCephei	07.4	57 42	3.6	K3	.014	− 5.1	0.5	−2.4	.006

TABLE 6—Cont.

Boss	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	Mt W. M	Vict. M	Spec. π
		h m	° ′							
5746	1 Lacert.	22 11.6	37 15	4.2	K4	.024	+ 4.9	0.4	−1.1	.009
5790	35 Pegasi	22.8	04 12	4.9	K1	.328	+62.4	1.8	+1.3	.019
5804	5 Lacert.	25.4	47 11	4.6	K2	.021	+ 0.2	−2.8	−3.7	.002
5843	.....	34.7	56 17	5.5	M5	.058	+19.4	.....	−1.7	.004
5940	βPegasi	58.9	27 32	2.6	M3	.234	+17.3	0.0	−1.6	.014
5952	55 Pegasi	23 02.0	08 52	4.7	M0	.019	+ 1.0	0.3	−0.2	.011
5976	Br. 3077	08.5	56 37	5.6	K5	2.105	− 9.9	7.2	+6.6	.158
5993	8 Androm.	13.1	48 28	5.0	M2	.040	+ 4.4	0.2	−0.7	.007
....	C 3081	26.5	58 37	6.8	K1	1.060	−14.8	5.6	+5.2	.048
6058	.....	28.5	21 57	5.5	M6	.037	+ 8.1	.....	−1.6	.004
6078	γCephei	35.2	77 04	3.4	K1	.167	−31.3	2.3	+3.2	.091
6121	.....	46.2	08 46	6.1	M3	.064	− 7.3	.....	−1.3	.003
6127	φPegasi	47.4	18 34	5.2	M4	.049	− 6.4	0.4	−0.3	.008

fairly well. The only place where there is any great divergence is in the mean for the K3 to K5 types, where this computation indicates that our values are too positive. As can be seen from Fig. 13, our values are already about one-half a magnitude brighter than the Mount Wilson ones and we have accordingly investigated these stars further. The stars common to our list and the Mount Wilson list were divided into four groups, the first consisting of all the K0, 1, 2 stars, the second, of the K3, 4, 5 stars, the third, of the K6, 7, 8, 9 stars and the fourth, of all the M stars, excluding μ Cephei. The mean absolute magnitude was computed for these groups from the three formulae. In the first computation the proper motions were used as given in Table 6. As is well known when the stars are of various magnitudes this tends to give the greatest weight to the brighter stars and a second solution was made reducing each μ to the mean magnitude of the group. A comparison of the results of all these groupings is given in Table 8.

The final conclusions that would be drawn from this table and Table 7 are that the absolute magnitudes derived by us for the K3-K5 stars in this list are three or four-tenths too positive and the Mount Wilson values are seven or eight-tenths too positive. In the M-types our values are about right or a little negative while

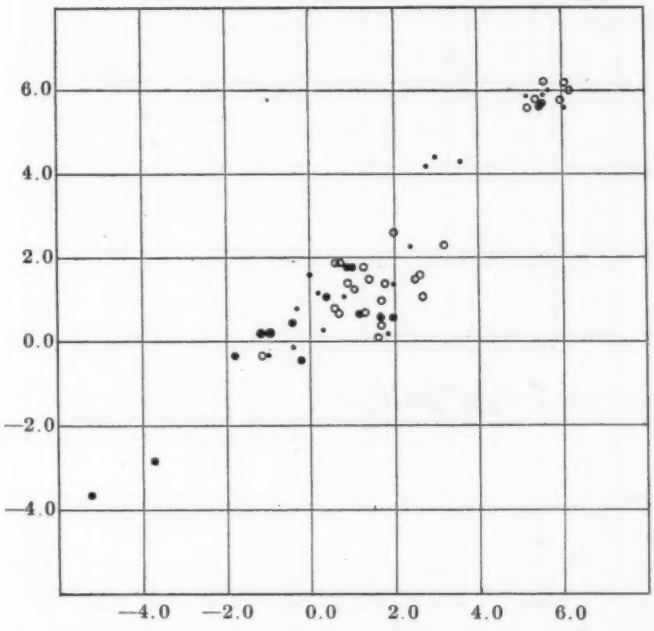

FIG. 12. Comparison of Victoria and Mount Wilson values for Types K0, 1, 2. Small dots are K0, open circles are K1 and filled circles K2.

the Mount Wilson values are positive. It has seemed to us difficult to alter our reduction curves so as to make the late K-types more negative and the M-types more positive and still retain the continuity. For this reason and also because more material is available from the Boss programme, we have let the original values stand.

Another method of dividing the stars into groups for the purposes of discussion and one that seemed logical was to use the Mount Wilson values. In this computation we omitted the types K0, 1, 2 because here there seemed to be general agreement between the results from the two observatories. The stars of types K3, 4, 5 and the M-types were investigated further. We divided each of these classes into two groups according to the value of the absolute magnitude assigned in the list of 1646 parallaxes, omitting

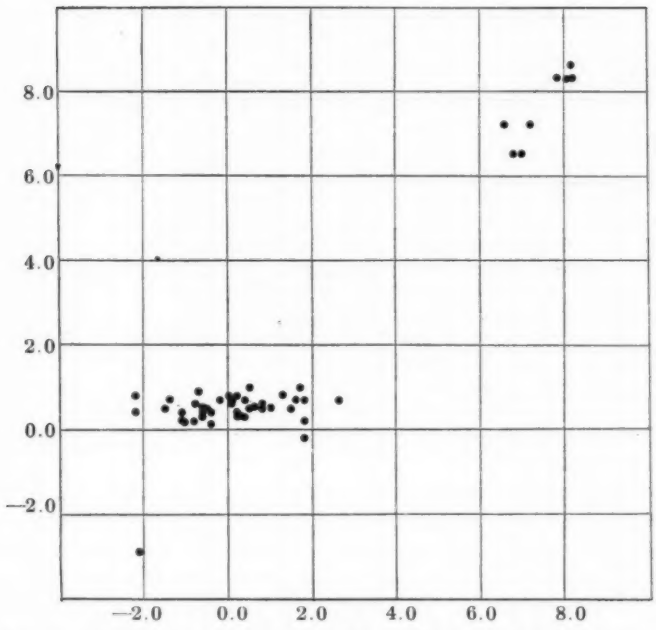

FIG. 13. Comparison of Victoria and Mount Wilson Absolute Magnitudes in Types K3-K9.

the Cepheids, and computed the mean absolute magnitudes. Table 9 shows the result of this computation.

The computed values for the various groups are not in good agreement with the spectroscopic ones obtained at either observatory and agree about as well with one as with the other, but the point that seems to us surprising is that in both the M and late K stars the slight difference shown by the Mount Wilson absolute magnitudes should divide the stars into groups yielding such widely different proper motions, values which differ out of all proportion to the variation in absolute magnitude.

In the figure illustrating the M-type stars the very discordant star is μ Cephei.

In addition to the lines so far published as showing a variation with absolute magnitude each observer has noted lines from time

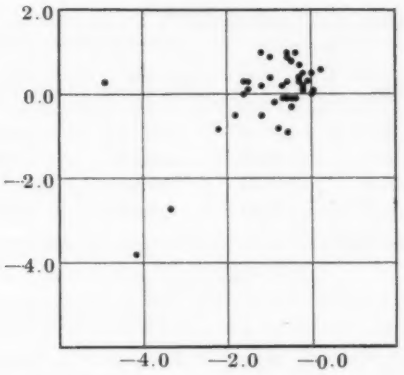

FIG. 14. Comparison of Victoria and Mount Wilson Absolute Magnitudes for M Types. Ordinates are Mount Wilson Values; abscissae are Victoria Values. The very discordant star is μ Cephei.

TABLE 7

No. Stars	Type	M from μ	M Young	M Harper	M Mt. Wilson
3	K2	−2.68	−3.87	−3.33	−2.28
5	K1	−1.32	−1.02	−0.72	−0.06
7	K1	−0.06	+0.03	−0.04	+0.73
16	K1	+1.41	+1.64	+1.52	+1.01
9	K1	+1.02	+0.99	+0.88	+1.27
8	K1	+3.39	+3.08	+2.81	+2.68
8	K4	−2.54	−1.74	−1.20	0.0
9	K4	−1.60	−0.51	−0.02	0.5
9	K4	+0.58	+1.55	+1.39	0.5
10	K7	+0.22	+0.40	+0.40	0.5
7	M2	−3.10	−3.25	−2.90	−1.5
24	M2	−0.75	−0.55	−1.20	0.2
12	M2	−0.30	−1.42	−0.64	0.2
11	M1	+0.21	+0.25	−0.24	0.3

to time that give promise of being useful. Among others we may mention the ratio of λλ4305 : 08. The inclusion of all the lines now known to vary with absolute magnitude would lead, we think, to a still further reduction of the accidental errors.

TABLE 8

No. Stars	Types	Absolute Magnitude			
		Victoria	Mt. Wilson	Computed I	Computed II
34	K0, 1, 2	+0.72	+0.77	+0.63	+0.90
26	K3, 4, 5	−0.05	+0.37	−0.65	−0.28
12	K6, 7, 8, 9	+0.23	+0.51	+0.27	+0.05
41	M0.....M5	−0.86	−0.08	−0.23	−0.54

TABLE 9

No. Stars	Types	Absolute Magnitude			
		Mt. Wilson	Victoria	Computed I	Computed II
10	K3, 4, 5	+0.20	−0.10	−2.40	−2.58
15	K3, 4, 5	+0.69	+0.14	−0.14	+0.03
16	M0...5	−0.26	−0.84	−0.93	−1.12
20	M0...5	+0.53	−0.60	+0.69	+0.45

For many of the stars the results from the various lines are somewhat discordant, very much more so than can be ascribed either to plate error or error of measurement. Several writers have pointed out that the spectroscopic method of measuring absolute magnitude is really dependent on a density-temperature effect and that the mass may enter as a disturbing factor. We would expect also that the spectroscopic binaries would give somewhat erroneous values and especially those showing double lines. In the latter case a correction to the apparent magnitude is legitimate but this does not overcome the difficulty of estimating ratios of intensities in the superimposed spectra. This interesting class of stars is being investigated further.

Summary

1. A search for spectral lines showing variations with luminosity has resulted in many new lines being discovered.

2. Fourteen lines, which include the five already known to show an effect have been used to derive absolute magnitudes.

3. A definite method of measurement has been worked out so that the work can be duplicated by other observers.

4. The parallaxes of 1082 stars have been derived.

5. The individual differences between our absolute magnitudes and those published by the Mount Wilson observers is quite large for many stars. The number of lines measured by us should make our accidental error small.

6. Preliminary investigation on this point not yet published leads us to hope that the accidental error for well exposed spectra is below one-fifth of an absolute magnitude.

7. For most of the types there is little systematic difference between our values and those derived at Mount Wilson.

8. In the late K-type giant stars our absolute magnitudes are quite contradictory to those obtained at Mount Wilson and we think the criteria which they used have mixed together in one class stars of widely different luminosities.

9. The stars with the c-characteristic have been shown to form a part of the stellar sequence, the difference in their spectra from other stars being one of degree only.

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NOTES ON THE CONSTELLATION ORION

By A. F. Miller

ALPHA Orionis (Betelgeuse), though generally seen inferior in brightness to Rigel, has not been always so. When Bayer made his *Atlas*, it was brighter than Beta (Rigel), and there are many other instances on record of similar brightness. Fletcher, in 1852, saw and described Betelgeuse brighter than Capella; Flammarion, in 1875, saw it brighter than Aldebaran, and in December, 1876, brighter than Rigel. In February and March, 1903, on several nights, I saw it brighter than Capella. At present it is brighter than Rigel. F. E. Seagrave in *Popular Astronomy* calls attention to its increase in brightness since last April. During the interval October 29-November 12 it was fully 2/10 of a magnitude brighter than Rigel. Its variability was first noticed by Sir John Herschel in 1836, and he thought he had found a period of 196 days, but this is incorrect. It is a long-period, irregular variable, sometimes considerably above first magnitude, sometimes as low as 1.6 magnitude. Its spectrum resembles that of Alpha Herculis, Aldebaran, and Antares, having a series of bright and dark bands; but adequate instruments show also many fine dark lines of the advanced solar type. Betelgeuse has a faint companion of the ninth magnitude, distant 160″.

Lambda Orionis was noted to be of the third magnitude by Hipparchus and Ptolemy; the latter called it "a nebulous star". This was explained by Al Sufi who saw a triangle of small stars close to it.

Gamma Orionis (Bellatrix) has been seen of the second magnitude since the earliest observations. It is a white star of the class termed "Orion stars".

Beta Orionis (Rigel) has been of the first magnitude since the earliest record. It is white, with a spectrum characteristic of the Orion stars, (contrary to former statements that its spectrum resembled that of Sirius and Vega). The lines are very fine and only shown by powerful instruments. (To me the star has a slightly

yellowish colour in the telescope, first noticed in 1884.) Rigel has a companion, distant 10″ at 201° (1877). I measured this object in January, 1903, and the result (the mean of 5 measures) was 10″.7 at 200°; however, the pair have remained practically unchanged for a very long period, and their proper motion also is almost imperceptible. The companion is itself a very close double, discovered by Burnham with his 6-inch, distance 0″.75, and motion indicates a binary system.

The three stars in "the Belt" are all doubles, but with the exception of Delta, which can be divided with a 2-inch telescope, they require good optical power. Epsilon and Zeta are of the second magnitude, although they do not seem as bright as Bellatrix.

Just below Zeta you may see Sigma Orionis, one of the most interesting multiple stars in the constellation. A moderate instrument shows a group of six connected stars; a larger telescope shows eight; with a 10-inch reflector I have seen ten; large instruments show many more.

Theta Orionis was so named by Bayer who saw only one star; Flamsteed noted two; Huygens, in 1656, saw three; Mairan, in 1758, saw four, thus depicting "the Trapezium". There are two much smaller stars associated with these, both visible with a 4-inch refractor. The trapezium stars have remained practically unchanged in position since they were first observed; but the small stars appear to be in orbital revolution around the stars nearest to them. All these stars are believed to be involved in the Great Nebula. Their spectra show a number of bright lines.

The Great Nebula itself gives a spectrum of a glowing gas. Three bright lines may be seen with any small spectroscope (two Hydrogen, the third "Nebulium"). Dr. Copeland first saw the Alpha line of Helium, which is not constantly visible, however.

Orion contains more interesting telescopic objects than any other constellation.

REVIEW OF PUBLICATIONS

The Wedge Method and its Application to Astronomical Spectrophotometry, by H. H. Plaskett, being No. 12, Vol. 2, pages 213-260 of the "Publications of the Dominion Astrophysical Observatory", 1923.

The use of the wedge method in spectrophotometry had its origin in some work by Mees and Wratten on the colour sensitivity of photographic plates and was later used by Merton and Nicholson in determining the relative intensities of the line spectra of hydrogen and helium. Mr. Plaskett is, however, the first to apply the method to astronomical problems such as the determination of the probable temperatures of the sun and stars. The theory of the method is quite simple and the experimental difficulties are not so great as those encountered in the use of the bolometer to study intensity distribution. Mr. Plaskett has done a very careful piece of work which gives promise of great usefulness in its application to astronomical problems.

The essential feature of this method of spectrophotometry is the use of a small neutral-tint wedge in front of the slit of the spectroscope so that the resultant spectrum on the plate resembles a range of mountains in which the height depends upon the distribution of intensity with wave length in the source, the absorption in the wedge and spectroscope, and the colour sensitivity of the plate. Of these various quantities it is desired to determine only *the intensity distribution in the spectrum of the source.*

The effect of the absorption in the spectroscope and the colour sensitivity of the plate are eliminated by taking under the same conditions and on the same plate a wedge spectrum of some standard source, the intensity distribution in the spectrum of which is known.

The Wedge Calibration.

The wedge was calibrated by the following method. The light from a constant source was arranged to fall on the slit in a uniform beam, and the plate was exposed for a measured time. The in-

tensity of the source was now cut down by a certain factor j and a second exposure made of the same source for the same time on an adjacent part of the same plate. For any value of λ points on the two spectra are now found which have the same density. The wedge constant is thus obtained since the ratio of the intensities transmitted by the wedge at the two points on the wedge corresponding to the two points of equal density of the spectra will be j.

The intensity of the source was varied by the factor j in two different ways. The first method was to vary the aperture of the lens used to concentrate the light from the source on the slit. Diaphragms with a large number of holes pierced in them were used to vary the lens aperture. The second method was to interpose between the source and the slit a slowly rotating variable sector.[1] These two methods gave very concordant results.

The Photometry.

Knowing the wedge constant, and given a comparison spectrum of a source of light of known distribution of intensity, the distribution of intensity in the unknown source may be at once determined photometrically. The photometry consists in the measurement of the heights h_1 and h_2 of two points on the two spectra having the same blackening. The relative intensities of the light of this wave length from the known and unknown sources is thus obtained. The microphotometer used in measuring densities was constructed by Mr. Plaskett from a Hartmann spectro-comparator and gave accurate readings.

The Use of Wedge Spectra to determine Colour Temperatures.

The "Colour Temperature" of a source is defined as that temperature at which a "black body" would have to be maintained

[1]The reviewer believes that the use of a rotating sector is here hardly permissible as a method of varying j. Whirling a sector of 120° aperture at a slow rate produces the same photographic effect as would be obtained by removing the sector and exposing for one-third of the time. This is not exactly the same as exposing to one-third of the intensity for the full time. The fact that the two methods of calibration were in such good agreement shows, however, that the reciprocity law was fairly near the truth here. A recent paper by Jones and Huse of the Eastman Kodak Co. Research Laboratory (Jour. Opt. Soc. America, 7, 1079; 1923) shows that for certain plates and for certain exposures the Schwarzschild constant is very nearly 1.

in order to give the same relative intensity distribution in the visible spectrum as the source. It has been well established that most sources of continuous spectra at very high temperatures have the same relative intensity distribution between 0.4μ and 0.7μ as has a black body maintained at certain definite temperatures. Given then the relative intensity distribution in the spectrum of a star, we may by the use of Wien's black body radiation law assign a "Colour Temperature" to the star.

The Colour Temperatures of some Laboratory Standards.

The wedge method was first tested out very rigidly by a study of the colour temperatures of the following standard laboratory sources: (1) The Eastman standard acetylene burner, colour temperature 2360 ± 10K. (2) A ribbon tungsten lamp supplied and calibrated by the Nela Research Laboratory of the General Electric Co. which was said by the Nela Laboratory to have the following colour temperatures: at 12 Amps. 2010K; at 16 Amps. 2439K; at 20 Amps. 2830K.

Taking the Nela lamp at 20 Amps. as standard, the wedge method gave for the lamp at 16 Amps. a temperature between 2419 and 2459K; and for the lamp at 12 Amps. between 1990 and 2030K, thus showing excellent agreement with the colour temperatures determined by the Nela Laboratory.

The temperature of the acetylene burner by a similar comparison was determined as 2340 ± 10K, as compared with the U.S. Bureau of Standards value of 2360 ± 10K.

These results prove then that the wedge method will reproduce accurately the relative intensity distribution in laboratory standards.

The Temperature of the Positive Crater of the Carbon Arc.

Using the acetylene burner and the tungsten lamp at 20 Amps. as standards, the colour temperature of the positive crater of the carbon arc was determined for cored carbons at a current of 5.6 Amps. Two carbons from the same batch gave colour temperatures of 3050 and 3125K, so that the temperature must depend to some extent on the carbon. The average value chosen by the author is 3080K, a value considerably lower than those given by

previous determinations. In most other studies, however, no allowance has been made for the effect of the two cyanogen bands at 0.42μ and 0.39μ.

No doubt the temperature varies for different carbons and for different currents, but even allowing for these factors the older determinations seem too high.

Relative Intensity Distribution in the Continuous Spectrum of the Sun.

Previous studies by Abbot and Wilsing have led to the conclusion that in the visible spectrum of the sun the intensity distribution does not correspond to that of a black body but shows a marked drop in the violet beyond 0.47μ.

The author's observations were made chiefly on July 21, 1921, with the 72-inch telescope and the universal spectroscope. Only the light from near the centre of the sun's image was used and the comparison spectrum was that of the carbon arc (T. 3080K). Regions of the spectrum were chosen for which there are fewest absorption lines and allowance was made for atmospheric absorption.

The author finds that to a close approximation *the continuous spectrum of the sun has the intensity distribution corresponding to that of a black body.*

The spectroscope had not sufficient dispersion to open out the narrow regions of pure continuous spectrum sufficiently to permit of an accurate determination of the colour temperature of the sun, but the author places the temperature between 6200° and 7000°K, the lower limit of which is considerably higher than the value of 5740°K determined from observations of the sun's total radiation.

Intensity Distribution in the Spectra of Six Typical Stars.

The stellar wedge spectra were secured with the 72-inch telescope and the universal spectroscope. All the exposures were made on two very transparent nights, November 6 and November 8, 1920. The "early type" stars were taken on Seed 30 plates and the "late type" stars on Ilford Panchromatic plates. The times of exposure varied from 23 to 45 minutes. The following results were obtained:

γ *Cassiopeiae.* The observed points do not fall very closely on the black body curve, but the general run of the values may be said to correspond to a temperature of 15000°K.

ϵ *Persei.* The observed points fit the 15000°K curve much more closely than in γ Cassiopeiae. In particular, it is to be noted, there is no evidence of a secondary maximum near 0.49μ.

α *Cygni.* Some difficulty was experienced in matching the observed points with a black body curve. The departures are probably to be attributed to accidental errors. The temperature is placed at 9000°K.

δ *Cassiopeiae.* A distribution corresponding to a temperature of 9000°K fits the observed values satisfactorily.

α *Aurigae.* The observed intensity distribution, exclusive of values to the violet of 0.46μ, corresponds to an intensity distribution between the temperatures of 5500°K and 6000°K. The drop in intensity of the observed values to the violet of 0.46μ is to be attributed to the effect of absorption lines which could not be entirely eliminated with the small linear dispersion and wide slit which were used.

β *Geminorum.* The observed values in this case depend only on two spectra, one of which was weak. An intensity distribution between the temperatures 5000°K and 5500°K fits the observed intensities, with the exception of those to the violet of 0.46μ. The depression in the violet is again the result of distortion by the absorption lines.

The results expressed as colour temperatures are given in the table below. In the third column is recorded the colour temperature as determined above by the wedge method. In the remaining three columns appear, where available, the temperatures determined radiometrically by Coblentz, with a visual spectrophotometer by Wilsing, Scheiner and Munch, and by Sampson's recent ingenious photographic method. From the table it will be observed that, while for G and K-type stars all methods in the hands of different observers yield concordant results, for the early type stars there appear striking discrepancies, the cause of which has yet to be elucidated. Further investigation may well be directed to the determination, not of colour temperatures, which may have

STELLAR TEMPERATURES

Star	Type	Wedge	Coblentz	Wilsing, etc.	Sampson
γ Cassiopeiae	Boe	15000°	.....	6800°	16900°
ϵ Persei	Bo	15000	.....	7400	.....
α Cygni	cA2	9000	9000°	9400	12500
δ Cassiopeiae	A5	9000	.....	5800	.....
α Aurigae	gGo+F5	5500-6000	6000	7100	5500
β Geminorum	Ko	5000-5500	5500	4900	.....

little physical significance, but of the actual relative intensity distribution in stars of types B and O.

W. H. MARTIN.

University of Toronto.

The Hindu Nakshatras, by Dhirendra Nath Mukhopadyaya, B.Sc. Reprinted from Vol. VI of the *Journal of the Department of Science*, Calcutta University. Calcutta University Press, 1923.

It is a satisfaction to observe the growth of scientific research in India. In various English and American journals there are to be continually found papers on physics, biology and other branches of science, while the first English translation of the original papers on the Einstein theory was issued from the Calcutta University Press.

The present reviewer is not an oriental scholar, but the contents of this publication are of very great general interest. It occupies 62 pages and deals with the nakshatras (or asterisms) used by the ancient Hindu astronomers. The author gives information regarding the system used in arranging the star-groups. This is a matter of importance, since, as he remarks, "With the identification of these, the whole history of the Aryan civilization, as presented in the Vedas, the only ancestral common heritage of us all, will be revealed to us".

The word 'nakshatra' is probably derived from two words meaning 'night' and 'preserve'—the dreariness of the night being relieved by the shining and brilliant luminaries in the heavens.

Starting from the star Revati (Zeta Piscium), the ecliptic was divided into twenty-seven equal portions, the names of which are given. According to him there are distinct references in the oldest

Vedic literature to the epoch when the vernal equinoctial colure passed through Jyestha (which included Antares) and Abhijit (Lyra), that is, 16,000-14,500 B.C.

The asterism preceding Jyestha was Anuradha (which included Delta Scorpii) and that preceding Anuradha was Visakha (containing portions of Scorpio and Libra). "With the vernal equinox in Visakha we have the second period (14,500-13,000 B.C.), when the year began with the month Kartika (the moon being full at the beginning of the period in the nakshatra Krittika—Pleiades). We have copious reference of this period being noticed in the Brahmanas and other Vedic literature; Krittika (Pleiades) was then the first of the nakshatras, not because the vernal equinox was then in Krittika, but because the year began with the full moon in it."

The author describes each of the nakshatras, indicating what stars, as we now know them, are included in them, and he gives a map of the equatorial belt of the sky at 12,200 B.C., at which time Vega was the pole star.

The author concludes as follows: "From the evidences produced before, it will be perfectly clear that all doubts of placing the Aryan civilization beyond 16,000 B.C. must vanish. . . . The importance of Abhijit, the southing and disappearance of Agastya (Canopus), his reappearance and the religious observances connected with it, the history of lots of other nakshatras clearly evince the extreme antiquity of the civilization of the Aryans before their dispersal and recent conversion into Christianity, Mahometanism, etc. Let us ponder over the numerous evidences left by our great ancestors scientifically and then we shall not hesitate a moment in declaring that ours is a civilization as ancient as any human record can show."

C. A. CHANT.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

Wisdom in Book Catalogues

It has been remarked that the advertisements in a newspaper are often more interesting than its news columns, and certain it is that some book catalogues contain more interesting reading than do many of the books mentioned therein. Among the interesting catalogues are those issued by a well-known London firm "Founded in Little Tower Street, City, in 1816." Not only do they contain the names of many works which the book-lover is searching for, but often a neatly-turned sentence describing the author and his book or containing a sage remark on the philosophy of life, compels one to read on until the last page.

In illustration of the above, the following extracts from a catalogue recently received are given, the details as to size and price being omitted.

Brewster (Sir David, F.R.S.). *The Martyrs of Science; or the Lives of Galileo, Tycho Brahe and Kepler*, 2nd edition, 1846.

But they all three died in their beds.

Clark (Josiah Latimer, F.R.S.; telegraph cable engineer). *Treatise on the Transit Instrument as applied to the Determination of Time, for the Use of Country Gentlemen* . . . published by the author, 1882.

'The motive of this little work is a desire to introduce the transit instrument into more common use, more especially as a means of obtaining true time for the regulation of clocks and watches. The writer believes if this charming instrument were fully known it would become as popular as the stereoscope or the camera.'—*Preface.*

But since then motoring and golf have come in, and Country Gentlemen cannot keep awake all night gazing at the stars.

Eclipse Expedition, 1870-1: *A MS. Copy of all the Expenses of the Scientific Staff* in Connexion with it, on about 100 ll., with Original Invoices, and the Treasurer's General Balance Sheet, 1870-1.

The balance sheet shows the cost to have been about £2,000, £1,500 of which were contributed by the Treasury. The private accounts give many interesting details, *e.g.*, luncheons, oysters, cigars, gloves, shirts, flowers, theatre tickets, etc.,

etc., which exhibit the human factor latent even in the austerest of the sciences, but whose total hardly amounts to the cost of one Official Lady Typist at the Peace Conference or its various peripatetic sequelae.

EISENSCHMIDT (Johann Caspar). *Diatribe de Figura Telluris elliptico-sphaeroide ubi una exhibetur eius Magnitudo per singulas Dimensiones, Consensu omnium Observationum comprobata*, editio princeps, 1691.

This work, through the author's contention of the earth being elongated towards the poles (like King Louis-Philippe's head), caused the long discussion on the figure of the earth which was only ended in 1736, by the result of Maupertuis and Bouguer's meridian-measurement.

SMYTH (Charles Piazzi, Astronomer-Royal for Scotland; son of Adml. Smyth). *Our Inheritance in the Great Pyramid*, new and enlarged edition, including all the most important discoveries up to the present time, 1874.

The Sphinx still smiles inscrutably at the long procession of discoverers of the secret of the Great Pyramid, now succeeded by the post-war profiteers in their parked Rolls-Royces, smoking their fat cigars and pulling at their long drinks and littering their torn *Daily Mails* about the desert sand.

PROCTOR (Richard Anthony, F.R.A.S.) and Arthur Cowper RANYARD, F.R.A.S. *Old and New Astronomy*, with 31 plates and 472 woodcuts. . . . 1892.

The author's *magnum opus*, designed to embody the studies of his life. It is one of the most complete and readable treatises on astronomy, and from the simplicity of its treatment specially to be recommended to amateur astronomers.

Proctor's scientific writings are as interesting to-day as at the time they were written, and will repay the reader's attention a hundred times more than the scientific inanities offered by the syndicated journalist of the present day.

BRYANT (Robert). *The Orbit of the Planet Sappho* (80) . . . with author's inscr. to Col. Tupman, 1889.

The only monograph on this planetoid, which has the distinction of being the only one ever discovered by photography. (The editor of the catalogue is far astray in this remark.—C. A. C.)

C. A. C.

MEETINGS OF THE SOCIETY

At Victoria

October 23, 1923.—A regular meeting of the society was held in the auditorium of the Girls' School at 8 p.m., the President, Mr. W. E. Harper, in the chair.

The President then gave a short address on the aims of the society and urged the desirability of obtaining new members.

Moved by Dr. Plaskett and seconded by Mr. E. E. Blackwood that a letter of condolence be forwarded to the relatives of Mr. A. W. McCurdy and Mr. J. R. Cowell. Carried.

Attention was drawn to the question box and an enquiry as to the effect of Relativity on a moving pendulum was replied to by Mr. H. H. Plaskett.

The President now invited Mr. F. Napier Denison to address the meeting on "Recent Severe Earthquakes."

Since last November a large number of severe earthquakes have occurred either under or in the vicinity of the Pacific Ocean. The great Japanese 'quake which, though one of the most disastrous on record as to loss of human life and property, was not as severe as several other recent ones which fortunately occurred either under the ocean or near thinly populated areas such as Kamchatka.

Illustrations were shown of the great earthquake zone, or line of weakness in the Earth's crust, which extends along the western coasts of the American Continent, to the south of the Aleutian Islands and Kamchatka, and is very pronounced off the eastern coast of the Japanese islands, where the great Tuscora Deep is situated. It was pointed out that the Japanese 'quake was caused by a horizontal pressure applied to the western side of the islands finally causing a fracture of the earth's crust a short distance off the west coast beneath the sea where the depth is nearly six miles.

A graphic description of the new British Milne-Shaw seismographs, which have been installed at the Gonzales Heights Observatory, was given, and interesting records from these instruments were shown.

These instruments are so delicate that they are now recording an average of nearly one earthquake per day.

In the case of the Japanese 'quake the intensity of the destructive waves was not so great as in other recent submarine 'quakes, but they were more prolonged, and they continued to be recorded here for nearly seven hours, as they moved to and from the antipodes of Japan.

In the case of the great Chilean 'quake of last November, which caused a great displacement under the sea, seismic sea waves spread over the Pacific, and were even recorded on the Victoria tide gauge. They were also noted on the coast of Japan. During the address it was pointed out that the earthquake zone

was not pronounced on the Coast of British Columbia, and though tremors will occur here, as they had done in the past, it is not expected that they will assume alarming proportions.

The paper was followed with much interest by those present. After a discussion a vote of thanks was tendered to Mr. Denison and the meeting terminated.

At London

The regular November meeting was held in the University of Western Ontario, on Friday, November 16, at 8.15 p.m., the President, Dr. Kingston, in the chair. On motion of Messrs. Saunders and Bowen it was decided to make part of the programme for the December meeting of a social character. Mrs. R. J. Bowen was appointed convener of the refreshment committee.

The lecture for the evening was given by Prof. J. W. Russell, M.A., head of the Geology Department, University of Western Ontario, on "Earthquakes and Volcanoes". Mr. Russell pointed out that it was commonly supposed that the centrosphere or nucleus of the earth was molten, but that this is now known to be incorrect. The molten centrosphere was a deduction from the fact that deep mines and wells showed that the temperature within the earth increased with the depth at the rate of about 1° C. for every 100 ft. of depth. This theory failed to take account of the great pressure that must be exerted in the depths of the earth. Also the rapidity with which waves caused by an earthquake shock travel proves that the centrosphere must be hard and elastic.

The lecturer showed by means of a map that certain parts of the earth are peculiarly susceptible to earthquakes and pointed out that Ontario is practically immune. Earthquake shocks were illustrated by considering the case of a marble on a marble floor. When the floor receives a hard blow the marble jumps up and exhibits a much greater motion than the floor. An earthquake shock is so violent that loose alluvial soil is thrown up a great distance while the hard rock beneath is disturbed much less. The Japanese therefore build their houses on solid rock rather than on loose soil.

Earthquakes are frequently followed by volcanic action. A number of slides were used to show the more striking volcanic mountains, among which was Mt. Shasta, 14,000 feet high, with a remarkably symmetrical cone.

Prof. Russell pointed out that in the final activity of volcanoes steam and gas escape, which are called mineralizers. These continue after volcanic action has ceased and are the source of all valuable ores. The lecture was followed by a spirited discussion.

On motion of Rev. R. J. Bowen and Mr. W. E. Saunders a hearty vote of thanks was extended to Prof. Russell for his interesting and illuminating address.

E. T. WHITE,
Secretary-Treasurer.

[Other minutes held over until next issue]

The Royal Astronomical Society of Canada

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